



**U.S. Department of Energy
National Nuclear Security Administration**

Livermore Field Office, Livermore, California 94551

Lawrence Livermore National Laboratory



Lawrence Livermore National Security, LLC, Livermore, California 94551

LLNL-AR-638895-DRAFT

**Draft Second Five-Year Review Report for the
Building 854 Operable Unit at
Lawrence Livermore National Laboratory Site 300**

Authors:

**J. Valett*
V. Dibley
M. Taffet
M. Buscheck*
L. Ferry**

Contributors:

A. Anderson*	Z. Demir
J. Radyk	A. Helmig
V. Madrid	A. Henke
G. Lorega	

June 20, 2013

**Weiss Associates, Emeryville, California*



Environmental Restoration Department

Draft Second Five-Year Review Report for the Building 854 Operable Unit at Lawrence Livermore National Laboratory Site 300

Authors:

**J. Valett*
V. Dibley
M. Taffet
M. Buscheck
L. Ferry**

Contributors:

A. Anderson*	Z. Demir
J. Radyk	A. Helmig
V. Madrid	A. Henke
G. Lorega	

June 20, 2013

*Weiss Associates, Emeryville, California



Environmental Restoration Department

Certification

I certify that the work presented in this report was performed under my supervision. To the best of my knowledge, the data contained herein are true and accurate, and the work was performed in accordance with professional standards.

Victor Madrid	Date
California Professional Geologist	
No. 5051	
License expires: April 30, 2014	
California Certified Hydrogeologist	
No. 378	
License expires: April 30, 2014	

**Approval for the
Second Five-Year Review for the
Building 854 Operable Unit at
Lawrence Livermore National Laboratory
Site 300**

Prepared by:

United States Department of Energy
National Nuclear Security Administration
Livermore Field Office
Livermore, California

Approved:

Claire S. Holtzapple

Date

Site 300 Remedial Project Manager
U.S. Department of Energy
National Nuclear Security Administration
Livermore Field Office

Five-Year Review Summary Form

SITE IDENTIFICATION		
Site name: Lawrence Livermore National Laboratory Site 300, Building 854 Operable Unit (OU)		
EPA ID: CA 2890090002		
Region: IX	State: California	City/County: San Joaquin/Alameda
SITE STATUS		
NPL status: Final		
Multiple OUs: Yes	Has the site achieved construction completion? Yes. September 28, 2007	
REVIEW STATUS		
Lead agency: United States (U.S.) Department of Energy (DOE)		
Author name: J. Valett		
Author title: Project Hydrogeologist	Author affiliation: Weiss Associates- Emeryville, California	
Review period: January 1, 2008 to January 1, 2013		
Date(s) of site inspection: May 9, 2012		
Type of review: Statutory		
Review number: 2		
Triggering action date: 2008 Five-Year Review for the Building 854 OU		
Due date: December 10, 2013		

Five-Year Review Summary Form (continued)

ISSUES/RECOMMENDATIONS				
OU(s) without Issues/Recommendations Identified in the Five-Year Review:				
Not applicable.				
OU(s): 6	Issue Category: No Issue			
	Issue: NA. The remedy is performing as intended and is demonstrating good progress in remediating the ground water. To further expedite the ground water cleanup, some follow-up actions are recommended.			
	Recommendation #1: At the 854-Source (SRC) ground water extraction and treatment system (GWTS), extraction wells W-854-02 and W-854-2218 are capable of pumping at higher sustainable flow rates. DOE/NNSA recommends: <ol style="list-style-type: none"> 1. Performing a pumping test at well W-854-2218 to determine the range of enhanced pumping rates and corresponding drawdown water levels. 2. Increasing the pumping rates of extraction wells W-854-02 and W-854-2218 to maximize flow rates and further increase hydraulic capture. 3. Evaluate the effluent discharge options at 854-SRC GWTS since the effluent is currently discharged via misting towers, which are at or near capacity. 			
Affect Current Protectiveness	Affect Future Protectiveness	Implementing Party	Oversight Party	Milestone Date
No	No	DOE	EPA/State	January 1, 2018

Five-Year Review Summary Form (continued)

ISSUES/RECOMMENDATIONS (Continued)				
OU(s): 6	Issue Category: No Issue			
	Issue: NA. The remedy is performing as intended and is demonstrating good progress in remediating the ground water. To further expedite the ground water cleanup, some follow-up actions are recommended.			
	Recommendation #2: Continue the evaluation of options for modifying the 854-PRX GWTS and effluent discharge method to accommodate increased flow from extraction well W-854-03. This well is capable of pumping at a higher flow rate; however, the pumping rate is currently constrained by the limited capacity of the nitrate biotreatment unit and the infiltration trench.			
Affect Current Protectiveness	Affect Future Protectiveness	Implementing Party	Oversight Party	Milestone Date
No	No	DOE	EPA/State	January 1, 2018
OU(s): 6	Issue Category: No Issue			
	Issue: NA. The remedy is performing as intended and is demonstrating good progress in remediating the ground water. To better monitor ground water cleanup progress, some follow-up actions are recommended.			
	Recommendation #3: Install at least one performance monitor well in the vicinity of 854-PRX extraction well W-854-03 to better estimate hydraulic capture and assess ground water cleanup progress in this area.			
Affect Current Protectiveness	Affect Future Protectiveness	Implementing Party	Oversight Party	Milestone Date
No	No	DOE	EPA/State	January 1, 2018

Five-Year Review Summary Form (continued)

ISSUES/RECOMMENDATIONS (Continued)				
OU(s): 6	Issue Category: No Issue			
	Issue: The remedy is performing as intended and is demonstrating good progress in remediating the ground water. To further expedite the ground water cleanup, some follow-up actions are recommended.			
	Recommendation #4: Continue to monitor perchlorate in ground water in Tnbs ₁ /Tnsc ₀ HSU monitor wells W-854-45 (near Building 858 approximately 1,000 ft south of 854-DIS) and W-854-1823 (approximately 300 ft southeast of 854-PRX). While perchlorate concentrations in these wells are slightly above the 6 µg/L MCL cleanup standard, concentrations trends are generally stable to decreasing. If monitoring over the next five years indicates that perchlorate concentrations in these wells stabilize and remain above the 6 µg/L MCL cleanup standard or show increasing trends, DOE/LLNL will discuss implementing remedial measures in or near these wells with the regulatory agencies.			
Affect Current Protectiveness	Affect Future Protectiveness	Implementing Party	Oversight Party	Milestone Date
No	No	DOE	EPA/State	January 1, 2018

Five-Year Review Summary Form (continued)

PROTECTIVENESS STATEMENT		
OU: 6	Protectiveness Determination Protective	Addendum Due Date: NA
<p>Protectiveness Statement: The remedy at the Building 854 OU currently protects human health and the environment in the short-term because there is no current exposure to site contamination. Exposure pathways that could result in unacceptable risk to onsite workers are being controlled by the implementation of institutional controls, the Health and Safety Plan, and the Contingency Plan. The remedy is protective in the long-term because institutional controls have been implemented to prevent potential future exposure to contaminated media, and the remedy will reduce contaminant of concern concentrations to meet cleanup standards.</p> <p>The cleanup standards for Building 854 OU ground water are drinking water standards. Because drinking water standards do not differentiate between industrial and residential use, the ground water cleanup remedy will be protective under any land use scenario.</p> <p>The cleanup standards for VOCs in subsurface soil are to reduce concentrations to mitigate risk to onsite workers and prevent further impacts to ground water to the extent technically and economically feasible. Because some VOCs may remain in subsurface soil following the achievement of these cleanup standards, a land use control prohibits the transfer of lands with unmitigated contamination that could cause potential harm under residential or unrestricted land use.</p> <p>The land use control consists of implementing a land use covenant per Title 22 California Code of Regulations (CCR), Division 4.5, Chapter 39, Section 67391, and deed restrictions per CERCLA 120(h) in the event that Site 300 property with unmitigated contamination that could cause potential harm under residential or unrestricted land use is transferred in the future. This land use control requirement is included in the Site-Wide ROD. This prohibition will remain in place until and unless a risk assessment is performed in accordance with current U.S. EPA risk assessment guidance and the DOE/NNSA, EPA, Department of Toxic Substances Control (DTSC), and Regional Water Quality Control Board (RWQCB) agree that it adequately shows that no unacceptable risk for residential or unrestricted land use is present.</p>		

This page intentionally left blank

Table of Contents

1. Introduction.....	1
1.1. General Services Area (GSA) OU (OU 1).....	2
1.1.1. Central GSA.....	2
1.1.2. Eastern GSA.....	3
1.2. Building 834 (OU 2)	3
1.3. Pit 6 Landfill (OU 3)	4
1.4. High Explosive (HE) Process Area (OU 4)	4
1.5. Building 850/Pit 7 Complex (OU 5).....	5
1.5.1. Building 850 Firing Table (OU 5)	5
1.5.2. Pit 7 Landfill Complex (OU 5)	6
1.6. Building 832 Canyon (OU 7).....	7
1.7. OU 8.....	7
1.7.1. Building 801 Dry Well and the Pit 8 Landfill (OU 8)	7
1.7.2. Building 833 (OU 8)	8
1.7.3. Building 845 Firing Table and the Pit 9 Landfill (OU 8)	8
1.7.4. Building 851 Firing Table (OU 8)	8
1.7.5. Pit 2 Landfill (OU 8).....	9
1.8. Building 812 (OU 9)	9
1.9. Building 865/Advanced Test Accelerator	9
2. Site Chronology.....	10
3. Background	12
3.1. Physical Characteristics	12
3.1.1. Site Description.....	12
3.1.2. Hydrogeologic Setting	13
3.2. Land and Resource Use.....	14
3.3. History of Contamination.....	15
3.4. Initial Response	16
3.5. Contaminants of Concern	16
3.6. Summary of Basis for Taking Action.....	16
4. Remedial Actions	17
4.1. Remedy Selection	17

4.2. Remedy Implementation	18
4.3. System Operations/Operation and Maintenance	19
4.4 Land Use Controls	21
4.4.1. Building 854 OU Land Use Control Objectives	22
4.4.2. Building 854 OU Land Use Controls.....	23
4.4.3. Summary of the Status of Building 854 Land Use Controls	26
5. Progress Since Last Review.....	26
5.1. Protectiveness Statement from Last Review	26
5.2. Recommendations and Follow-up Actions from the 2008 Five-Year Review	26
5.3. Results of Implemented Actions	27
5.4. Status of Other Prior Issues	30
6. Five-Year Review Process	30
6.1. Notification of Review/Community Involvement.....	30
6.2. Identification of Five-Year Review Team Members.....	30
6.3. Document Review.....	31
6.4. Data Review and Evaluation.....	31
6.4.1. Vadose Zone Remediation Progress	31
6.4.2. Ground Water Remediation Progress	33
6.4.3. Risk Mitigation Remediation Progress	41
6.5. Interviews and Site Inspection	43
7. Technical Assessment	43
7.1. Remedy Function	43
7.2. Changes to Exposure Assumptions, Toxicity Data, Cleanup Levels, and Remedial Action Objectives.....	44
7.3. Other Information	45
8. Issues	45
9. Recommendations and Follow-Up Actions.....	45
10. Protectiveness Statement.....	46
11. Next Review	47
12. References	48
13. Acronyms and Abbreviations	54

List of Figures

- Figure 1. Location of LLNL Site 300 and the Building 854 Operable Unit.
- Figure 2. Site 300 map showing Operable Unit locations.
- Figure 3. Site map showing monitor, extraction, injection and water-supply wells, and treatment facilities.
- Figure 4. Summary of stratigraphy and hydrostratigraphic units.
- Figure 5. Hydrogeologic cross-section A-A' showing total VOC concentrations.
- Figure 6. Hydrogeologic cross-section A-A' showing perchlorate concentrations.
- Figure 7. Ground water potentiometric surface map for the Tnbs₁/Tnsc₀ hydrostratigraphic unit, including hydraulic capture zones.
- Figure 8. Building 854 Operable Unit land use controls.
- Figure 9. Time-series plot of TCE in ground water in monitor well W-854-09.
- Figure 10. Building 854-Source soil vapor extraction system: operational history and historical trichloroethene (TCE) vapor concentrations in parts per million on a volume-to-volume basis (ppm_{v/v}).
- Figure 11. Time-series plots of cumulative mass of total VOCs removed by ground water extraction at each Building 854 treatment facility.
- Figure 12. Time-series plots of cumulative mass of perchlorate removed by ground water extraction at each Building 854 treatment facility.
- Figure 13. Comparison of the existing extraction wells and the distribution of total VOCs in ground water in the Tnbs₁/Tnsc₀ hydrostratigraphic unit in the second semester 2007 and the second semester 2012.
- Figure 14. Comparison of the existing extraction wells and the distribution of perchlorate in ground water in the Tnbs₁/Tnsc₀ hydrostratigraphic unit in the second semester 2007 and the second semester 2012.
- Figure 15. Map showing total VOC isoconcentration contours for the Tnbs₁/Tnsc₀ hydrostratigraphic unit.
- Figure 16. Map showing perchlorate isoconcentration contours for the Tnbs₁/Tnsc₀ hydrostratigraphic unit.
- Figure 17. Map showing nitrate concentrations for the Tnbs₁/Tnsc₀ hydrostratigraphic unit.
- Figure 18. Time-series plots of perchlorate in ground water in monitor wells W-854-45 and W-854-1823.
- Figure 19. Map showing ground water elevations, total VOCs, perchlorate, and nitrate concentrations for the combined Qls/Tnbs₁ hydrostratigraphic unit.
- Figure 20. Time-series plots of a) total VOCs, b) perchlorate and c) nitrate in ground water in the Building 854-Source area extraction wells and monthly facility flow.
- Figure 21. Time-series plots of a) total VOCs, b) perchlorate and c) nitrate in ground water in the Building 854-Proximal Area extraction wells and monthly facility flow.
- Figure 22. Time-series plots of a) total VOCs, b) perchlorate and c) nitrate in ground water in the Building 854-Distal Area extraction wells and monthly facility flow.

List of Tables

- Table 1. Actual annual costs for the Building 854 Operable Unit for fiscal years 2008 through 2012.
- Table 2. Description of Land Use Controls (institutional and engineered) for the Building 854 Operable Unit.

List of Attachments

- Attachment A. Evidence of Denitrification in Building 854 Operable Unit Ground Water.
- Attachment B. Building 854 Operable Unit Five-Year Review Inspection Checklist.

1. Introduction

The United States (U.S.) Department of Energy (DOE)/National Nuclear Security Administration (NNSA) has conducted a Five-Year Review of the remedial actions implemented at the Building 854 Operable Unit (OU) at Lawrence Livermore National Laboratory (LLNL) Site 300. Environmental cleanup is conducted under the oversight of the U.S. Environmental Protection Agency (EPA), the California Department of Toxic Substances Control (DTSC), and the California Regional Water Quality Control Board (RWQCB) – Central Valley Region. DOE/NNSA is the lead agency for environmental restoration at LLNL. The review documented in this report was conducted from January 2008 through January 2013. Parties providing analyses in support of the review include:

- U.S. DOE/NNSA, Livermore Field Office.
- LLNL, Environmental Restoration Department (ERD).
- Weiss Associates.

The purpose of a Five-Year Review is to evaluate the implementation and performance of a remedy to determine whether the remedy is currently protective and will continue to be protective of human health and the environment. The Five-Year Review report presents the methods, findings, and conclusions of the review. In addition, the Five-Year Review identifies issues or deficiencies in the selected remedy, if any, and presents recommendations to address them. The format and content of this document is consistent with guidance issued by DOE (DOE, 2002) and the U.S. EPA (EPA, 2001).

Section 121 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendment Reauthorization Act (SARA), requires that remedial actions that result in any hazardous substances, pollutants, or contaminants remaining at the site be subject to a Five-Year Review. The National Contingency Plan further provides that remedial actions which result in any hazardous substances, pollutants, or contaminants remaining at the site above levels that allow for unlimited use and unrestricted exposure be reviewed every five years to ensure protection of human health and the environment. Consistent with Executive Order 12580, Federal agencies are responsible for ensuring that Five-Year Reviews are conducted at sites where five-year reviews are required or appropriate.

LLNL Site 300 (Figure 1) has been divided into nine OUs based on the nature and extent of contamination to effectively manage site cleanup (Figure 2):

- General Services Area (GSA) (OU 1) including the Central and Eastern GSA.
- Building 834 (OU 2).
- Pit 6 Landfill (OU 3).
- High Explosives (HE) Process Area (OU 4) including Building 815, the HE Lagoons, and the HE Burn Pit.
- Building 850/Pit 7 Complex (OU 5).
- Building 854 (OU 6).
- Building 832 Canyon (OU 7) including Buildings 830 and 832.

- Site-Wide (OU 8) including Buildings 801, 833, 845, and 851 and the Pit 2, 8, 9 Landfills.
- Building 812 (OU 9).

Five-year reviews are conducted individually for each OU at Site 300, except for OUs 3 and 8. The Construction Completion Report (Holtzapfel, 2008) completed on January 18, 2008 and Site-Wide Record of Decision (ROD) (U.S. DOE, 2008) completed on July 10, 2008 are the triggers for the five-year reviews for OUs 3 and 8, respectively, in accordance with EPA guidance. At the other OUs where construction began prior to the Site-Wide ROD as treatability studies and/or removal actions, DOE/NNSA and the regulatory agencies agreed to use the completion of the OU-specific Remedial Design reports as the triggers for the first five-year reviews.

This is the second Five-Year Review for the Building 854 OU (OU 6). The first Five-Year Review was completed in 2008 (Dibley et al., 2008a). This review is considered a statutory review because: (1) contamination will remain onsite upon completion of the remedial action, (2) the Record of Decision was signed after October 17, 1986 (the effective date of the SARA), and (3) the remedial action was selected under the CERCLA. The triggering action for the first review was the December 15, 2003 submittal date of the Interim Remedial Design for the Building 854 Operable Unit at Lawrence Livermore National Laboratory Site 300 (Daily et al., 2003).

The background and description of the Building 854 OU are presented in Section 3. The following sections include the descriptions and status of the other OUs and areas where environmental restoration activities are occurring at Site 300.

1.1. General Services Area (GSA) OU (OU 1)

The GSA OU has been separated into the Central GSA and the Eastern GSA based on differences in hydrogeology and the distribution of environmental contaminants. DOE has performed three Five-Year Reviews for the GSA OU (Ferry et al., 2001a; Dibley et al., 2006; and Valett et al., 2011). The Third Five-Year Review for the GSA determined that additional offsite land use controls are necessary for long-term protectiveness due to the presence of contamination in offsite ground water. The fourth Five-Year Review is scheduled for 2016.

1.1.1. Central GSA

Chlorinated solvents, mainly trichloroethene (TCE), were used as degreasing agents in craft shops in the Central GSA. Rinse water from these degreasing operations was disposed of in dry wells that were gravel-filled holes about 3 to 4 feet (ft) deep and 2 ft in diameter. As a result, subsurface soil and ground water were contaminated with volatile organic compounds (VOCs). There are no contaminants of concern (COCs) in surface soil in the central GSA. The Central GSA dry wells were used until 1982. In 1983 and 1984, these dry wells were decommissioned and excavated.

Ground water cleanup began in the Central GSA in 1992 and soil vapor extraction started in 1994 as removal actions. In 1997, a Final ROD for the GSA OU (U.S. DOE, 1997) was signed and ground water and soil vapor extraction and treatment continued as a remedial action. The selected remedy for the Central GSA includes monitoring, risk and hazard management including land use controls, and ground water and soil vapor extraction and treatment. The

remedial design was completed in 1998 and construction completion for the OU was documented in September 2005.

Operation of the ground water and soil vapor extraction and treatment systems to remove VOCs from the subsurface is ongoing. Remediation has reduced maximum VOC concentrations in ground water from 272,000 micrograms per liter ($\mu\text{g/L}$) in 1992 to 520 $\mu\text{g/L}$ in 2012 and has mitigated the risk to onsite workers from inhalation of VOCs inside Building 875.

1.1.2. Eastern GSA

The source of contamination in the Eastern GSA is an abandoned debris burial trench that received craft shop debris. Leaching of solvents from the debris resulted in the release of VOCs to ground water.

Ground water cleanup began in the Eastern GSA in 1991 as a removal action. In 1997, a Final ROD for the GSA OU was signed and ground water extraction and treatment continued as a remedial action. The remedial design was completed in 1998 and construction completion for the OU was documented in September 2005. A ground water extraction and treatment system operated from 1991 to 2007 to remove VOCs from ground water.

By 2005, VOC concentrations in both onsite and offsite ground water in the Eastern GSA area had been reduced to below the drinking water Maximum Contaminant Cleanup (MCL) cleanup standards. In February 2007, the ground water extraction and treatment system was shut down with regulatory concurrence. DOE/NNSA continued to monitor ground water for five years, during which time VOC concentrations remained below the MCL cleanup standards, indicating that ground water cleanup had been successfully completed in the Eastern GSA. A Draft Close-out Report for the Eastern GSA was submitted to the regulatory agencies in December 2012 (Dibley and Ferry, 2012).

1.2. Building 834 (OU 2)

From 1962 to 1978, intermittent spills and piping leaks resulted in contamination of the subsurface soil and rock and ground water with VOCs and silicone oils (tetrabutyl orthosilicate/tetrakis (2-ethylbutyl) silane [TBOS/TKEBs]). Nitrate in ground water results from septic system effluent but may also have natural sources. There are no COCs in surface soil.

Completed remedial activities include excavating VOC-contaminated soil (1983) and installing a surface water drainage diversion system to prevent rainwater infiltration in the contaminant source area (1998). Ground water and soil vapor extraction and treatment began in 1986 as treatability studies. An area-specific Interim ROD for the Building 834 OU (U.S. DOE, 1995) was superseded by the Interim Site-Wide ROD and subsequent 2008 Site-Wide ROD. The Building 834 OU remedy includes monitoring, risk and hazard management including land use controls, and ground water and soil vapor extraction and treatment. Significant *in situ* bioremediation is occurring in Building 834 ground water and a treatability study focusing on understanding and enhancing this process has been conducted. The remedial design was completed in 2002 and construction completion for the OU was achieved in September 2005.

Remediation has reduced VOC concentrations in ground water from a historical maximum of 1,060,000 $\mu\text{g/L}$ in W-834-D3 to a maximum of 300,000 $\mu\text{g/L}$ in 2012. TBOS/TKEBs in ground water has also been reduced from a historic maximum concentration of 7,300,000 $\mu\text{g/L}$ in 1995

to 35,600 µg/L in 2012. While nitrate concentrations have decreased from a historic maximum of 749 milligrams per liter (mg/L) in 2000 to 300 mg/L in 2012, the continued elevated nitrate concentrations indicate an ongoing source of ground water nitrate. It is likely that there are multiple sources of nitrate at Building 834. One possible anthropogenic source is the septic system leachfield located in the vicinity of well W-834-S1. A second probable source is natural soil nitrate. Additional sources could be nitrogenous compounds, like nitric acid or barium nitrate, that might have inadvertently been discharged into the septic system via a test cell floor drain or to the ground during accidental spills and/or pipeline leaks that released TCE to the environment. Anaerobic bacteria in the Building 834 Core and T2 areas reduce nitrate locally by denitrification.

DOE has performed three Five-Year Reviews for the Building 834 OU (Ferry et al., 2002a, Dibley et al., 2007a, and Valett et al., 2012).

1.3. Pit 6 Landfill (OU 3)

From 1964 to 1973, approximately 1,900 cubic yards (yd³) of waste from LLNL Livermore Site and Lawrence Berkeley Laboratory was buried in nine unlined trenches and animal pits at the Pit 6 Landfill. Infiltrating rainwater leached contaminants from pit waste resulting in tritium, VOC, and perchlorate contamination in ground water. Nitrate contamination in ground water results from septic system effluent. No COCs were identified in surface or subsurface soil.

In 1971, DOE excavated portions of the waste contaminated with depleted uranium. In 1997, a landfill cap was installed as a CERCLA removal action to prevent infiltrating precipitation from further leaching contaminants from the waste. Because of decreasing VOC concentrations in ground water, the presence of TCE degradation products, and the short half-life of tritium (12.3 years), the selected remedy for VOCs and tritium at the Pit 6 Landfill is monitored natural attenuation (MNA). Because ground water monitoring data for perchlorate and nitrate are limited, DOE/NNSA will continue to monitor ground water to determine if and when an active remedy for these contaminants might be necessary. The remedy also includes risk and hazard management. Construction completion was achieved in October 2002. No Remedial Design document was required for this area.

The extent of contamination at the Pit 6 Landfill is limited and continues to decrease with concentrations/activities near and below cleanup standards. Natural attenuation has reduced total VOCs in ground water from a historic maximum of 250 µg/L in 1988 to 8.7 µg/L in 2012. Tritium activities are well below the cleanup standard and continue to decrease towards background levels. Perchlorate is not currently detected in any wells above the 4 µg/L reporting limit. The extent of nitrate at concentrations exceeding the cleanup standard continues to be limited to one well. Installation of the landfill cap mitigated the onsite worker inhalation risk.

DOE has performed one Five-Year Review for this OU (Buscheck et al., 2013).

1.4. High Explosive (HE) Process Area (OU 4)

From 1958 to 1986, surface spills at the drum storage and dispensing area for the former Building 815 steam plant resulted in the release of VOCs to ground water, subsurface soil, and bedrock. HE compounds, nitrate, and perchlorate detected in ground water are attributed to wastewater discharges to former unlined rinse water lagoons that occurred from the 1950s to

1985. VOCs, nitrate, and perchlorate have also been identified as COCs in ground water near the former HE Burn Pits. VOCs have been identified as COCs in surface water at Spring 5. HE compounds are the COCs in surface soil. HE compounds and VOCs are the COCs in subsurface soil. No further action was selected as the remedy for VOCs and High-Melting Explosive (HMX) in surface and subsurface soil.

The HE Open Burn Facility was capped under the Resource Conservation and Recovery Act (RCRA) in 1998. In 1999, DOE implemented a CERCLA removal action to extract ground water at the site boundary and prevent offsite TCE migration. The HE Process Area remedy includes: (1) ground water extraction and treatment for VOCs, HE compounds, and perchlorate, and (2) monitored natural attenuation (MNA) for nitrate (except at Building 829 where nitrate is extracted and treated), (3) monitoring, and (4) risk and hazard management including land use controls. The remedial design was completed in 2002. Construction completion for the OU was achieved in September 2007. Six ground water extraction and treatment systems currently operate in the OU.

Ground water remediation efforts have reduced total VOC concentrations from a historic maximum of 1,013 µg/L in 1993 to 54 µg/L in 2012. Perchlorate concentrations have decreased from a historic maximum of 50 µg/L in 1998 to 28 µg/L in 2012. Research Department Explosive (RDX) in ground water has been reduced from a maximum historic concentration of 350 µg/L in 1988 to 168 µg/L in 2012. Natural denitrification processes are reducing nitrate concentrations in ground water to background levels. Remediation has also mitigated risk to onsite workers in the HE Process Area OU.

DOE has performed two Five-Year Reviews for the High Explosives Process Area OU (Dibley et al., 2007b and Helmig et al., 2012). The Second Five-Year Review for the High Explosives Process Area determined that additional off-site land use controls are necessary for long-term protectiveness due to the presence of contamination in offsite ground water. The next Five-Year Review Report is scheduled for 2017.

1.5. Building 850/Pit 7 Complex (OU 5)

This OU has been divided into two areas for cleanup evaluation purposes: (1) the Building 850 Firing Table area, and (2) the Pit 7 Complex.

A Remedial Action Completion Report for the Building 850/Pit 7 Complex OU was completed in 2011 (Dibley et al., 2011a). The first Five-Year Review for this OU is scheduled for 2016.

1.5.1. Building 850 Firing Table (OU 5)

High-explosives experiments were conducted at the Building 850 Firing Table from 1958 to 2008. Tritium was used in some of these experiments, primarily between 1963 and 1978. As a result of the destruction and dispersal of test assembly debris during detonations, surface soil was contaminated with metals, polychlorinated biphenyls (PCBs), dioxins, furans, HMX, and depleted uranium. Leaching from firing table debris has resulted in tritium and depleted uranium contamination in subsurface soil and ground water. Nitrate and perchlorate are also COCs in ground water. Tritium is the only COC in surface water (Well 8 Spring).

Gravel was removed from the firing table in 1988 and placed in the Pit 7 Landfill. PCB-contaminated shrapnel and debris were removed from the area around the firing table in

1998. The Building 850 remedy consists of MNA, monitoring, and risk and hazard management including land use controls. A remedial design was completed in 2004. The remedial design included the excavation and offsite disposal of contaminated surface soil and sand pile. This remedy was not implemented due to a large increase in transportation and offsite disposal costs. DOE and the regulatory agencies agreed to perform remediation of contaminated surface soil as a non-time critical removal action. An Engineering Evaluation/Cost Analysis (Dibley et al., 2008b) and Action Memorandum (Dibley et al., 2008c) were completed in 2008. A removal action was completed in 2010 for the excavation and solidification of PCB-, dioxin-, and furan-contaminated soil and sand pile. Metals, HMX, and uranium in surface soil at Building 850 do not pose a risk to human health or threat to ground water, therefore a no further action remedy was selected. However, these constituents in surface soil were removed during the soil excavation/solidification removal action.

Natural attenuation has reduced tritium activities from a historic maximum of 566,000 picoCuries per liter (pCi/L) in 1985 to 38,300 pCi/L in 2012. Uranium activities are below the cleanup standard and are within the range of natural background levels. The extent of nitrate with concentrations above cleanup standards is limited and does not pose a threat to human health or the environment. The maximum perchlorate concentration in 2012 is 62 µg/L, and a treatability study to evaluate *in situ* biodegradation of perchlorate is in progress.

1.5.2. Pit 7 Landfill Complex (OU 5)

The Pit 3, 4, 5, and 7 Landfills are collectively designated the Pit 7 Landfill Complex. Firing table debris containing tritium, depleted uranium, and metals was placed in the pits in the 1950s through the 1980s. The Pit 4 and 7 Landfills were capped in 1992. During years of above-normal rainfall (i.e., 1997-1998 El Niño event), ground water rose into the bottom of the landfills and the underlying contaminated bedrock. This resulted in the release of tritium, uranium, VOCs, perchlorate, and nitrate to ground water. There are no COCs in surface water or surface soil. Tritium and depleted uranium are COCs in subsurface soil.

DOE and the regulatory agencies agreed that the Pit 7 Complex required additional study; accordingly, this area was not included in the 2001 Interim ROD and an area-specific Remedial Investigation/Feasibility Study (Taffet et al., 2005) was completed. An Amendment to the Interim ROD for the Pit 7 Complex was signed in 2007 (U.S. DOE, 2007) that described the selected remedy for the Pit 7 Complex including monitoring, risk and hazard management including land use controls, MNA, ground water extraction and treatment, and source control. The interim remedial design was completed in 2008. A hydraulic drainage diversion system was constructed in 2008 to control contaminant sources by preventing ground water from rising into the pit waste and underlying contaminated bedrock. Also, a ground water extraction and treatment system was constructed in 2009-2010 to treat uranium, nitrate, perchlorate, and VOCs in ground water.

Natural attenuation has reduced tritium activities in ground water from a historic maximum of 2,660,000 pCi/L in 1998 to 233,000 pCi/L in 2012 and has mitigated risk to onsite workers from inhalation of tritium vapors. Uranium activities have also decreased from a historic maximum of 781 pCi/L in 1998 to 94 pCi/L in 2012. VOC concentrations are currently near or below cleanup standards. Nitrate concentrations in ground water remain relatively stable, while perchlorate concentrations have decreased.

1.6. Building 832 Canyon (OU 7)

Contaminants were released from Buildings 830 and 832 through piping leaks and surface spills during past activities at these buildings. VOCs, nitrate, and perchlorate are the COCs in ground water. VOCs are the COCs in surface water at Spring 3. VOCs, nitrate, and HMX are the COCs in subsurface soil. HMX is also a COC in surface soil. No further action was selected as the remedy for HMX and nitrate in surface and subsurface soil.

Ground water and soil vapor extraction and treatment have been conducted since 1999 to reduce contamination in ground water and subsurface soil. The Building 832 Canyon OU remedy includes monitoring, risk and hazard management including land use controls, MNA for nitrate, and ground water and soil vapor extraction and treatment. The interim remedial design was completed in 2006. Construction completion for the OU was achieved in September 2007. Three ground water extraction and treatment systems and two soil vapor extraction and treatment systems currently operate in this OU.

Remediation has reduced total VOC concentrations from a historical maximum of 13,000 µg/L in 2003 to 2,900 µg/L in 2012. Perchlorate concentrations have been reduced from a historical maximum of 51 µg/L in 1998 to 13 µg/L in 2012. Nitrate concentrations in ground water remain fairly stable, and are possibly the result of the ongoing contribution of nitrate from septic systems and natural bedrock sources. Nevertheless, natural denitrification processes continue to reduce nitrate concentrations to background levels near the site boundary. Remediation has also mitigated the risk to onsite workers in several locations in the Building 832 Canyon OU.

A Five-Year Review of remediation in the Building 832 Canyon OU was completed in August 2011 (Helmig et al., 2011). The second Five-Year-Review is scheduled for 2016.

1.7. OU 8

Operable Unit 8 includes the contaminant release sites that have a monitoring-only remedy: the Building 801 Dry Well and Pit 8 Landfill, Building 833, Building 845 and Pit 9 Landfill, the Building 851 Firing Table, and the Pit 2 Landfill. OU 8 release sites have a monitoring-only interim remedy because either: (1) contaminants in surface and subsurface soil/bedrock do not pose a risk to humans or plant and animal populations or a threat to ground water, (2) there is no ground water contamination, (3) contaminant concentrations in ground water do not exceed cleanup standards, and/or (4) the extent of contamination in ground water is limited. The first Five-Year Review for this OU is scheduled for 2013. These release sites are summarized below.

DOE has performed one Five-Year Review for this OU (Buscheck et al., 2013).

1.7.1. Building 801 Dry Well and the Pit 8 Landfill (OU 8)

The Building 801 Firing Table was used for explosives testing and operations resulting in contamination of adjacent soil with metals and uranium. Use of this firing table was discontinued in 1998, and the firing table gravel and some underlying soil were removed. Waste fluid was discharged to a dry well (sump) located adjacent to Building 801D from the late 1950s to 1984. The dry well was decommissioned and filled with concrete in 1984. VOCs, perchlorate and nitrate are COCs in ground water due to the past releases from the Building 801 Dry Well. VOC and nitrate concentrations in ground water are currently near or below cleanup standards or

at background levels. Perchlorate is not currently detected in ground water. VOCs are COCs in subsurface soil, but do not pose a risk to human health. The adjacent Pit 8 Landfill received debris from the Building 801 Firing Table until 1974, when it was covered with compacted soil. There is no evidence of contaminant releases from the landfill.

The selected remedy for this area includes monitoring and risk and hazard management including land use controls. No further action was selected as the remedy for VOCs in subsurface soil at Building 801.

No Remedial Design documents are required for this area.

1.7.2. Building 833 (OU 8)

TCE was used as a heat-exchange fluid in the Building 833 area from 1959 to 1982 and was released through spills and rinse water disposal, resulting in TCE-contamination of subsurface soil and shallow perched ground water. No contamination has been detected in the deeper regional aquifer. No COCs were identified surface soil at Building 833.

The selected remedy for Building 833 includes monitoring and risk and hazard management including land use controls. No Remedial Design document is required for this area. Ground water monitoring at Building 833 has shown a decline in total VOC concentrations from a historic maximum of 2,100 µg/L in 1992 to 120 µg/L in 2012.

1.7.3. Building 845 Firing Table and the Pit 9 Landfill (OU 8)

The Building 845 Firing Table was used from 1958 until 1963 to conduct explosives experiments. Leaching from firing table debris resulted in minor contamination of subsurface soil with depleted uranium and HMX but no unacceptable risk to human or ecological receptors or threat to ground water was identified. No contaminants have been detected in surface soil or in ground water at the Building 845 Firing Table. Prior to 1968, debris, debris generated at the Building 845 Firing Table was buried in the Pit 9 Landfill. There has been no evidence of contaminant releases from the Pit 9 Landfill.

The selected remedy for Building 845 and the Pit 9 Landfill includes monitoring and risk and hazard management including land use controls. No further action was selected as the remedy for uranium and HMX in subsurface soil at Building 845. No Remedial Design documents are required for this area.

1.7.4. Building 851 Firing Table (OU 8)

The Building 851 Firing Table has been used for high-explosives research since 1962. VOCs and uranium-238 were identified as COCs in subsurface soil, and Research Department explosive (RDX), uranium-238, and metals as surface soil COCs. However, there is no risk to humans or animal populations, or threat to ground water associated with these contaminants in surface and subsurface soil. Uranium-238 was identified as a COC in ground water. However, it poses no risk to human or ecological receptors, and uranium activities are well below cleanup standards and within the range of background levels.

In 1988, the firing table gravel was removed and disposed in Pit 7. Gravel has been replaced periodically since then. The selected remedy for Building 851 includes monitoring and risk and hazard management including land use controls. No further action was selected as the remedy

for VOCs and uranium in surface and subsurface soil, and for RDX and metal in surface soil at Building 851. No Remedial Design document is required for this area.

1.7.5. Pit 2 Landfill (OU 8)

The Pit 2 Landfill was used from 1956 until 1960 to dispose of firing table debris from Buildings 801 and 802. Ground water data indicate a discharge of potable water conducted from 1996 to 2005 to support a red-legged frog habitat located upgradient from the landfill may have leached depleted uranium from the buried waste. The frogs were relocated and the water discharge was discontinued, thereby removing the leaching mechanism. No contaminants were identified in surface or subsurface soil at the Pit 2 Landfill. No risk to human or ecological receptors has been identified at the Pit 2 Landfill.

The selected remedy for the Pit 2 Landfill includes monitoring and risk and hazard management including land use controls. Monitoring data indicate that uranium activities remain below the cleanup standard. No Remedial Design document is required for this area.

1.8. Building 812 (OU 9)

The Building 812 Complex was built in the late 1950s-early 1960s and was used to conduct explosives tests and diagnostics until 2008. A Characterization Summary Report for this area was completed in 2005 (Ferry and Holtzapple, 2005). The Building 812 Complex was designated as OU 9 in March 2007 based on characterization results that indicated the presence of uranium, metals, VOCs, HE compounds, nitrate, and perchlorate in environmental media. In 2008, a draft Remedial Investigation/Feasibility Study (RI/FS) describing the results of characterization activities and remedial alternatives for the Building 812 OU was submitted to the regulatory agencies. A DOE task force reviewed the soil-washing alternative and determined that it would not be effective at Site 300; therefore a soil-washing treatability study will not be performed. DOE is currently evaluating a new remedial strategy for contaminated soil at Building 812. Additional characterization began in 2011. A new RI/FS will be prepared following the completion of the characterization in 2013. A Proposed Plan will subsequently present the alternatives and a preferred remedy for public comment. A remedy will then be selected in an Amendment to the Site-Wide ROD.

1.9. Building 865/Advanced Test Accelerator

Building 865 facilities were used to conduct high-energy laser tests and diagnostics in support of national defense programs from 1980 to 1995. The Building 865 Complex housed a 275-foot linear electron accelerator called the Advanced Test Accelerator (ATA). The ATA was designed to produce a repetitively pulsed electron beam for charged particle beam research. In 2006, a Characterization Summary Report for this area was submitted to the regulatory agencies (Ferry and Holtzapple, 2006). Freon 113, Freon 11, and tetrachloroethene (PCE) were identified as COCs in ground water. However, concentrations of Freon 11 and Freon 113 are well below their MCLs; and PCE is only detected in one well at a concentration above its MCL. The remediation pathway for Building 865 is currently being negotiated.

2. Site Chronology

The chronology of important events at the Building 854 OU is summarized below.

1959

- Former water-supply Well 13 was drilled.

1960-1973

- Building 855 was used for the disassembly of test devices. A disposal lagoon was used for the disposal of liquids generated during Building 855 operations.

1967-1986

- Two TCE brine systems were installed and extensively used at the Building 854 Complex. TCE was released to subsurface soil through leaks and discharges of TCE-based heat-exchange fluid from the TCE brine system.

1983

- TCE-contaminated soil was excavated near Buildings 854F and 854H in the Building 854 Complex.

1989

- Brine systems were removed from the Building 854 Complex.

1990

- LLNL Site 300 was placed on the National Priorities List.

1992

- A Federal Facility Agreement for Site 300 was signed.

1994

- The Site-Wide Remedial Investigation report for Site 300 was issued in 1994 (Webster-Scholten et al., 1994).

1996

- Water-supply well 13 was sealed and abandoned because TCE was detected in this well and it was a potential vertical conduit for contaminant migration.

1998

- Submitted the Building 854 Operable Unit Characterization Summary (Ziagos and Reber-Cox, 1998).

1999

- The Site-Wide Feasibility Study for Site 300 was issued (Ferry et al., 1999).
- Ground water extraction and treatment was initiated in the Building 854 source area as a treatability study.

2000

- Ground water extraction and treatment was initiated in the Building 854 proximal area as a treatability study.

2001

- An Interim Site-Wide ROD for Site 300 was signed that selected an interim remedy for the Building 854 OU. The Interim Site-Wide ROD did not contain ground water cleanup standards.
- A Remedial Design Work Plan was issued that contained the strategic approach and schedule to implement the remedies in the Interim Site-Wide ROD (Ferry et al., 2001b).

2002

- Submitted the Compliance Monitoring Plan/Contingency Plan for Interim Remedies (Ferry et al., 2002b).
- Submitted the Building 854 Operable Unit Characterization Summary (Ferry and Kearns, 2002).

2003

- Submitted the Building 854 Interim Remedial Design Report (Daily et al., 2003).

2004

- Risk evaluation performed for the 2004 Annual Compliance Monitoring Plan (Dibley et al., 2005a) indicated there was no longer an onsite worker risk from the inhalation of VOCs volatilizing from the subsurface into outdoor air in the vicinity of Building 854F.

2005

- Excavated 100 cubic yards of contaminated soil from the former Building 855 disposal lagoon mitigating the onsite worker risk from the inhalation, ingestion, and dermal contact with PCB-, dioxin-, and furan-contaminated soil (Holtzapple, 2005).
- Initiated a soil vapor extraction (SVE) treatability study in the Building 854 source area.
- HE processing and machining operations started at Building 855.
- Building 854F was demolished, therefore mitigating the onsite worker risk from the inhalation of VOCs volatilizing from the subsurface into indoor air inside Building 854F. Buildings 854B, C, D, E, G, and J were also decontaminated and demolished.

2006

- Expanded the extraction wellfield in the Building 854 source area.
- Building 854H was converted to an HE magazine.
- Ground water extraction and treatment was initiated in the Building 854 distal area.
- Risk evaluation performed for the 2006 Annual Compliance Monitoring Report (Dibley et al., 2007c) indicated there was no longer an onsite worker risk from the inhalation of VOCs volatilizing from the subsurface into indoor air inside Building 854A.

2007

- Modified the treatment system in the Building 854 proximal area to increase extraction from the proximal wellfield.
- Construction of the interim remedy was completed.

2008

- EPA performed the construction completion inspection of the OU.
- The Site-Wide ROD was signed that selected remedies and cleanup standards for Site 300 including the Building 854 OU.

2009

- Revised the Compliance Monitoring Plan/Contingency Plan for the final remedies for Site 300 (Dibley et al., 2009a).

2010

- In October 2010, due to low yield, extraction well W-854-17 was taken offline and converted to a monitor well.

2011

- Building 854A was periodically occupied and used as a control room for large explosive experiments conducted at Building 851.

3. Background

3.1. Physical Characteristics

3.1.1. Site Description

LLNL Site 300 is a U.S. DOE experimental test facility operated by the Lawrence Livermore National Security (LLNS), Limited Liability Corporation. It is located in the Eastern Altamont Hills 17 miles east of Livermore, California (Figure 1). At Site 300, DOE conducts research development, and testing associated with high-explosive materials. Historic Site 300 operations involved the release of a number of contaminants to the environment. These releases occurred primarily from spills, leaking pipes, leaching from unlined landfills and pits, high explosive test detonations, and disposal of waste fluids in lagoons and dry wells (sumps). The climate at Site 300 is semi-arid; approximately 10 to 15 inches of precipitation falls each year, mostly in the winter.

The Building 854 OU covers an area of approximately 1.5 square miles in the western portion of LLNL Site 300 (Figure 2). Fifteen buildings were built in the OU between 1959 and 1970 including the Building 854 Complex (Buildings 854A, B, C, D, E, F, G, H, J and V), the Building 855 Complex (Buildings 855A, B, and C), Building 856, and Building 857 (Figure 3). The Building 854 Complex was used to test the stability of weapons and weapon components under various environmental conditions and mechanical and thermal stresses. In 1967, two TCE brine systems were installed at Building 854. The primary loop connected Buildings 854B and 854G and the secondary loop connected Buildings 854C, 854D, 854E and 854F. TCE was released to the subsurface in the Building 854 OU through leaks and discharges of TCE-based heat-exchange fluid from the secondary TCE brine system, primarily from outdoor valve stations and from piping between buildings. Both loops were extensively used until 1986, infrequently used after 1986, and removed in 1989. In 2005, Buildings 854B, C, D, E, F, G and J were decontaminated and demolished. Building 854V is still used as an HE magazine and Building 854H was converted to an HE magazine in 2006. In 2005, HE processing and

machining operations started at Building 855, which had been unoccupied for a number of years. In 2011, Building 854A was periodically occupied and used as a control room for large explosive experiments conducted at Building 851.

Three ground water extraction and treatment systems (GWTS) and one soil vapor extraction and treatment system (SVTS) are currently in place and operating to remediate VOCs, nitrate and perchlorate. To evaluate the progress of remediation, ground water is monitored for these constituents in all monitor, extraction and guard wells. The locations of existing monitor, extraction and water-supply wells and treatment facilities are shown on Figure 3.

3.1.2. Hydrogeologic Setting

This section describes the general hydrogeologic setting for the Building 854 OU including the unsaturated zone and the four hydrostratigraphic units (HSUs) underlying the area. An HSU is a water-bearing zone that exhibits similar hydraulic and geochemical properties. A conceptual hydrostratigraphic column for the northern portion of Site 300 including the Building 854 area is shown on Figure 4. Hydrogeologic cross-sections showing the HSUs and the vertical distribution of total VOCs and perchlorate in the Building 854 OU are shown on Figures 5 and 6, respectively.

3.1.2.1. Vadose (Unsaturated) Zone

The vadose zone is approximately 100 ft thick and consists of up to 70 ft of poorly consolidated Quaternary landslide deposits (Qls) and the unsaturated portion of the lower Neroly Tnbs₁ sandstone.

3.1.2.2. Saturated Zone

The four HSUs underlying the Building 854 OU are described below.

Qls and Tnbs₁ HSUs – The Qls HSU is an unconfined, ephemeral water-bearing zone that occurs in sand, silt, and angular, weathered bedrock fragments within landslide deposits. It ranges up to 100 ft in total thickness, and the saturated thickness is spatially and temporally variable depending on seasonal rainfall. The Qls HSU is recharged by surface water runoff and direct rainfall infiltration. Discharge occurs at Springs 10 and 11, located at the toe of the landslide deposit in a canyon in the southern part of the OU. The landslide is underlain by up to 200 ft of sandstone, siltstone, and claystone of the lower Neroly Formation. When saturated, the depth to Qls HSU ground water ranges from 75 ft to 88 ft below ground surface (bgs). Ground water in the Qls HSU is unconfined and generally flows in a south-southeast direction. Ground water in the Tnbs₁ HSU is generally unconfined and perched and occurs intermittently in the upper portion of the lower Tnbs₁ sandstone and is not hydraulically connected to the underlying Tnsc₀ siltstone/claystone. In portions of the Building 854 OU, ground water in the Qls and Tnbs₁ is hydraulically connected, and constitutes a single HSU (Qls/Tnbs₁ HSU).

Tnbs₁/Tnsc₀ HSU – The Tnbs₁/Tnsc₀ HSU is comprised of the lower Tnbs₁ sandstone and underlying Tnsc₀ siltstone/claystone fractured bedrock, and is present throughout the Building 854 OU. The saturated thickness of the HSU varies from tens of feet near the upgradient recharge area to over 100 ft in downgradient areas. The depth to ground water ranges from 90 to 180 ft bgs. Ground water in this HSU is unconfined.

Hydrologic, chemical, and optical televiewer data indicate that fractures are important flow-controlling features in the Tnbs₁/Tnsc₀ HSU. The magnitude and speed of water level response observed during pumping tests suggests preferential flow within fractures. Fracture orientation also appears to influence the Tnbs₁/Tnsc₀ ground water flow direction. In the northern portion of the OU, ground water generally flows east-southeast. In the central and southern portions of the site, ground water generally flows south (Figure 7).

Tnsc₀ HSU – The Tnsc₀ HSU at Building 854 consists of interbedded siltstone, claystone, and silty sandstone. This HSU contains ground water that exhibits distinctly different elevations and hydrographs from the overlying Tnbs₁/Tnsc₀ and underlying Tmss HSUs. The Tnsc₀ HSU is monitored in two wells, W-854-01 located in the Building 854 source area, and W-854-1701 located in the distal area. No anthropogenic contaminants have been detected in Tnsc₀ HSU ground water in the Building 854 OU.

Tmss HSU – The Tmss HSU is comprised of sandstone, claystone, and pebble conglomerate bedrock of the Cierbo Formation, and is present throughout the Building 854 OU. The potentiometric surface for this HSU is separate and distinct from the overlying Neroly water-bearing zone, and the upper part of the Cierbo Formation is unsaturated beneath the Building 854 source area. The saturated thickness of the Tmss HSU in the Building 854 area is not known; this unit has never been fully penetrated during drilling in support of historic environmental investigations. The depth to ground water averages approximately 300 ft bgs. Ground water in this HSU is confined. No anthropogenic contaminants have been detected in Tmss HSU ground water in the Building 854 OU.

3.1.2.3. Surface Water

Two springs, Springs 10 and 11, are located in the Building 854 OU, approximately 2,400 ft southeast of Building 855 (Figure 3). Springs 10 and 11 are perennial springs with flow rates of 0.5 and 0.1 gallons per minute (gpm), respectively. Water in these springs likely arises from ground water discharging at the toe of the Qls deposits.

3.2. Land and Resource Use

Before DOE established Site 300 as a remote testing facility in 1955, the area was used for cattle grazing. Site 300 is currently an operating facility, and will remain under DOE control for the reasonably anticipated future. Less than 5 percent of the 7,000 acres comprising Site 300 is developed. There have been no changes in land, building or ground water use in the Building 854 OU since the Site-Wide ROD was signed in 2008, other than the anticipated changes in onsite water-supply uses described below. In addition, Building 854A was reactivated and is being periodically used as office space. No other changes in land, building or ground water use are anticipated.

The Building 854 OU is entirely surrounded by Site 300 property and does not extend to the site boundary. The Building 854 OU is accessible only to DOE/LLNL workers.

Land use adjacent to the site boundary closest to the Building 854 OU consists of private rangeland and the Carnegie State Vehicular Recreation Area (SVRA). The nearest major population center (Tracy, California) is 8.5 miles to the northeast. There is no known planned modification or proposed development of the offsite rangeland closest to the OU. The SVRA continues to expand its infrastructure to accommodate increased public usage.

At Site 300, ground water is used for a variety of onsite water-supply needs including cooling towers, HE processing, dust control, drinking water and fire suppression. Site 300 plans to transition to the Hetch Hetchy water supply in the near future. No active water-supply wells are located near the Building 854 OU.

Site 300 has unique environmental qualities, largely because it has not been grazed for over 50 years and contains several habitat types and numerous special status species (e.g., threatened and endangered species, migratory birds, and rare plants). Special status species likely to occur within the Building 854 OU include the large-flowered fiddleneck (*Amsinckia grandiflora*, Federal endangered), the valley elderberry long horn beetle (*Desmocerus californicus dimorphus*, Federal threatened), the California red-legged frog (*Rana draytonii*, Federal threatened), and the Alameda whipsnake (*Masticophis lateralis euryxanthus*, Federal threatened). Habitat for the San Joaquin kit fox (*Vulpes macrotis mutica*, Federal and State endangered) occurs at Site 300, but no individuals have been observed.

The blue elderberry bush (*Sambucus mexicana*), host plant for the valley elderberry long horn beetle, occurs in the western part of the OU. California red-legged frog has been observed in the springs and wetlands in the western and southern portion of the OU. All of Site 300 is designated as critical habitat for this species. The northern part of the OU resides within California tiger salamander (*Ambystoma californiense*) upland habitat. The southwestern quadrant of Site 300, encompassing the entire Building 854 OU, is critical habitat for the Alameda whipsnake.

The large-flowered fiddleneck occurs in the southeastern part of the OU. An *Amsinckia grandiflora* Reserve was designated per a memorandum of agreement between DOE and the U.S. Fish and Wildlife Service, and consists of 160 acres of Site 300. This reserve is located partially within the Building 854 OU. Small numbers of the big tarplant (*Blepharizonia plumosa*), a California Native Plant Society (CNPS) List 1B plant (this list includes plants that are rare, threatened, or endangered), have been observed along roads and fire trails within the OU. However, as described in the most recent Site 300 rare plant report (Carlsen et al., 2012, Figure B19), no significant populations of this plant occurs within the Building 854 OU. Populations of the diamond-petaled poppy (*Eschscholzia rhombipetala*), a CNPS List 1B plant, occur in the western and southern portion of the OU. Populations of the round-leaved filaree (*California macrophylla*), a CNPS List 1B plant, occur in the northwestern portion of the OU.

3.3. History of Contamination

TCE was released to subsurface soil in the Building 854 OU through leaks and discharges of TCE-based heat-exchange fluid from the TCE brine system. These leaks occurred primarily from outdoor valve stations and piping between buildings, or from waste fluid discharge practices that are no longer permitted at Site 300. Most spills are believed to have occurred between 1967 and 1984 (Stupfel, 1992). Nitrate and perchlorate are also detected in ground water. Although the distribution of these contaminants does not suggest a specific source, the presence of HE compounds in soil may indicate an anthropogenic contribution. Septic systems serving the Building 854 and 855 Complexes are also possible sources of anthropogenic nitrate.

Historical records indicated that wastewater containing PCB oils were discharged from Building 855A to a former lagoon, south of the building. The HE compound HMX, metals, and tritium have been detected in soil in the Building 854 OU.

3.4. Initial Response

DOE began environmental investigations in the Building 854 area in 1983. Since then, 44 boreholes have been drilled in the OU, 33 of which were completed as ground water monitor wells (Figure 3). The geologic and chemical data from these wells and boreholes have been used to characterize the site hydrogeology and to monitor temporal and spatial changes in saturation and dissolved contaminants. Site characterization also included surface soil sampling, soil vapor flux chamber measurements, soil vapor surveys, hydraulic testing, and soil vapor extraction testing.

As summarized in Section 2, remediation activities at the Building 854 OU conducted prior to the Interim Site-Wide ROD included sealing and abandoning water-supply Well 13, and the excavation of TCE-contaminated soil near Buildings 854F and H. In addition, ground water extraction and treatment was initiated in 1999 with the installation of a ground water treatment system (GWTS) in the Building 854 source area. A GWTS was installed in the Building 854 proximal area in 2000 and in the distal area in 2006.

3.5. Contaminants of Concern

COCs in surface soil in the Building 854 OU include lead, zinc, HMX, PCBs, and tritium. No unacceptable risk or hazard to human health or ecological receptors has been identified for lead, zinc, HMX, or tritium in the Building 854 area. A baseline human health risk of 7×10^{-5} was calculated for onsite worker inhalation, ingestion, and direct dermal contact with PCB-contaminated soil.

TCE is the only COC in subsurface soil/rock in the Building 854 OU. Baseline cancer risks of 1×10^{-6} and 9×10^{-6} were calculated for onsite worker inhalation of TCE volatilizing from the subsurface into indoor air at Buildings 854A and 854F, respectively. A baseline cancer risk of 1×10^{-5} was calculated for onsite worker inhalation of TCE volatilizing from the subsurface into outdoor air at Building 854F.

COCs in ground water at the Building 854 OU are TCE, perchlorate, and nitrate.

There are no COCs in surface water in the Building 854 OU.

3.6. Summary of Basis for Taking Action

Remedial actions were initiated in the Building 854 OU to address: (1) unacceptable human health risks associated with onsite worker inhalation exposure to VOCs volatilizing from subsurface soil into indoor air inside Building 854A and 854F and outdoor air in the vicinity of Building 854F, (2) an unacceptable human health risk was associated with onsite worker inhalation, ingestion, and direct dermal contact with PCB-, dioxin-, and furan-contaminated soil, and (3) TCE, nitrate, and perchlorate present in ground water at concentrations exceeding MCL cleanup standards.

4. Remedial Actions

4.1. Remedy Selection

The remedy selected for the Building 854 OU is intended to achieve the following Remedial Action Objectives (RAOs):

For Human Health Protection:

- Restore ground water containing contaminant concentrations above cleanup standards.
- Prevent human ingestion of ground water containing contaminant concentrations (single carcinogen) above cleanup standards.
- Prevent human incidental ingestion and direct dermal contact with PCBs, dioxins, and furans in surface soil that pose an excess cancer risk greater than 10^{-6} or hazard index greater than 1, a cumulative cancer risk (all carcinogens) in excess of 10^{-4} , or a cumulative hazard index (all noncarcinogens) greater than 1.
- Prevent human inhalation of VOCs volatilizing from subsurface soil to air that pose an excess cancer risk greater than 10^{-6} or hazard index greater than 1, a cumulative excess cancer risk (all carcinogens) in excess of 10^{-4} , or a cumulative hazard index (all noncarcinogens) greater than 1.
- Prevent human inhalation of PCBs, dioxins and furans bound to resuspended surface soil particles that pose an excess cancer risk greater than 10^{-6} or hazard index greater than 1, a cumulative excess cancer risk (all carcinogens) in excess of 10^{-4} , or a cumulative hazard index (all noncarcinogens) greater than 1.
- Prevent human exposure to contaminants in media of concern that pose a cumulative excess cancer risk (all carcinogens) greater than 10^{-4} and/or a cumulative hazard index greater than one (all noncarcinogens).

For Environmental Protection:

- Restore water quality to ground water cleanup standards within a reasonable timeframe and to prevent plume migration to the extent technically and economically practicable. Maintain existing water quality that complies with ground water cleanup standards to the extent technically and economically practicable. This will apply to both individual and multiple constituents that have additive toxicology or carcinogenic effects.
- Ensure ecological receptors important at the individual level of ecological organization (listed threatened or endangered, State of California species of special concern) do not reside in areas where relevant hazard indices exceed 1.
- Ensure existing contaminant conditions do not change so as to threaten wildlife populations and vegetation communities.

An RAO for human health protection/applicable or relevant and appropriate requirements (ARAR) compliance for ingestion of surface waters (i.e., water from Site 300 springs) was not developed because there is not a complete exposure pathway for ingestion of surface waters for humans at Site 300. Humans do not drink water from Site 300 springs. In addition, the springs in which contaminants are detected do not produce a sufficient quantity of water to be used as a water-supply (greater than 200 gallons per day). VOC concentrations in Springs 10 and 11 were below reporting limits in the second semester of 2012.

In the 2001 Interim Site-Wide ROD, the remedy for the Building 854 OU was selected based on its ability to contain contaminant sources, prevent further plume migration, remove contaminant mass from the subsurface, and protect human health and the environment. The interim remedy was selected as the final remedy in the 2008 ROD.

The selected remedy for the Building 854 OU consisted of:

1. Ground water monitoring to evaluate the effectiveness of the remedial action, to determine when cleanup standards are met, and to ensure there is no impact to downgradient water-supply wells.
2. Risk and hazard management to prevent onsite worker exposure to VOCs volatilizing from subsurface soil until risk and hazard are mitigated through active remediation. Annual risk re-evaluation indicates that the inhalation risk for VOCs volatilizing from subsurface soil at Buildings 854A and 854F has been mitigated through remediation. Risk and hazard associated with PCB, dioxin, and furan contaminated surface and subsurface soil was also mitigated through remediation. Therefore, risk and hazard management for these exposure pathways are no longer necessary. Institutional/land use controls have been implemented to prevent human exposure to contamination and to protect the integrity of the remedy. The institutional/land use controls for the Building 854 OU are described in Section 4.4 and Table 2.
3. Extracting and treating VOCs, perchlorate and nitrate in ground water to mitigate unacceptable VOC inhalation risk for onsite workers, prevent further impacts to ground water and offsite plume migration, and reduce contaminant concentrations in ground water to cleanup standards.

4.2. Remedy Implementation

A GWTS has been operating in the Building 854 OU since 1999, first as a treatability study and then under the Interim Site-Wide ROD, and continues under the Site-Wide ROD. Three GWTSs currently operate in the Building 854 OU: Building 854-Source (854-SRC), Building 854-Proximal (854-PRX), and Building 854-Distal (854-DIS). A SVTS system also operates at 854-SRC. Treatment facility locations are shown on Figure 3.

The 854-SRC GWTS began operation in December 1999 removing VOCs and perchlorate from ground water. Ground water extraction was expanded in September 2006 from one well, W-854-02, extracting at a flow rate of approximately 1 gpm, to include wells W-854-18A, W-854-17, and W-854-2218 extracting at an approximate combined flow rate of 1.7 gpm. In October 2010, well W-854-17 was converted to a monitor well due to a very low sustainable flow rate; the facility has extracted from the three remaining wells since then. The GWTS configuration includes a particulate filtration system, two ion-exchange resin columns connected in series for perchlorate removal, and two aqueous-phase granular activated carbon (GAC) units connected in series for VOC removal. Nitrate-bearing treated effluent is then discharged via a misting tower onto the landscape for uptake and utilization of the nitrate by indigenous grasses.

A SVTS began operation at the 854-SRC in November 2005. Soil vapor is currently extracted from well W-854-1834 at an approximate flow rate of 45 to 50 standard cubic feet per minute (scfm). This system consists of vapor-phase GAC to remove VOCs from extracted soil vapor. Treated vapors are discharged to the atmosphere under a permit issued by the San Joaquin Valley Air Pollution Control District.

The 854-PRX GWTS began operation in November 2000 removing VOCs, nitrate and perchlorate from ground water. Ground water is currently extracted at an approximate flow rate of 1.5 gpm from well W-854-03, located southeast of the Building 854 complex. The GWTS configuration includes two ion-exchange resin columns connected in-series for perchlorate removal, three aqueous-phase GAC units connected in series for VOC removal. Although an aboveground containerized wetland biotreatment system for nitrate removal is still in place, it has not been necessary to utilize this system due to decreasing nitrate concentrations. The influent nitrate concentrations have been below the discharge limit of 45 mg/L since February 2010. The treated effluent water is discharged into an infiltration trench. In 2007, the treatment system was modified to replace the solar power with site power to increase the volume of extracted ground water by operating the GWTS 24 hours a day.

The 854-DIS GWTS is solar-powered and began operation in July 2006 removing VOCs and perchlorate from ground water. Ground water is extracted from well W-854-2139. The current operational flow rate averaged over time is approximately 700 to 800 gallons per month. The GWTS configuration includes two ion-exchange resin columns connected in series for perchlorate treatment followed by three aqueous-phase GAC units connected in series for VOC removal prior to discharge to an infiltration trench.

In 2005, approximately 100 cubic yards of PCB-, dioxin-, and furan-contaminated surface and shallow subsurface soil from the former Building 855 lagoon were excavated and disposed at an offsite landfill (Holtzaple, 2005).

4.3. System Operations/Operation and Maintenance

The Building 854 OU ground water extraction and treatment systems are operating as designed and no significant operations, performance, maintenance, or cost issues were identified during this review. All required documentation is in place, and treatment system operations and maintenance (O&M) activities are consistent with established procedures and protocols.

O&M procedures are contained in the following documents:

- Health and Safety Plan and Quality Assurance/Quality Control Plan for the O&M of the HEPA Treatment Facilities, contained within the Interim Remedial Design document.
- Operations and Maintenance Manual for Miniature Treatment Units, Ground Water Treatment Units, and Solar Treatment Units, Volume 13 (Martins, 2007).
- Operations and Maintenance Manual, Volume 1: Treatment Facility Quality Assurance and Documentation (LLNL, 2004).
- Integration Work Sheet Safety Procedure #11341: Ground Water and Soil Vapor Treatment Facility Operations at Site 300.
- Integration Work Sheet Safety Procedure #11314: Environmental Restoration Department (ERD) Site 300 Ion Exchange Resin Emplacement.
- Integration Work Sheet Safety Procedure #11313: ERD Site 300 Off-Road Driving Training.
- Integration Work Sheet Safety Procedure #11343: ERD Routine Ground Water Sampling & Water Level Monitoring at Site 300.

- Integration Work Sheet Safety Procedure #14984: ERD Routine Electronic Operations at Site 300.
- Integration Work Sheet Safety Procedure #11339: ERD Site 300 Hydraulic Pump Operation.
- Integration Work Sheet Safety Procedure #11346: Spent Aqueous and Vapor-phase Granular Activated Carbon (GAC) Replacement at Site 300.
- LLNL Livermore Site and Site 300 Environmental Restoration Project Standard Operating Procedures (Goodrich and Lorega, 2009).
- Building 854 OU Substantive Requirements and the Monitoring and Reporting Program issued by the California RWQCB.
- Site-Wide Compliance Monitoring Plan/Contingency Plan for Remedies at LLNL Site 300.

Monitoring and optimizing the performance and efficiency of the extraction and treatment systems comprises a large portion of the O&M activities. Maintenance activities performed during the five-year review period were documented in the semiannual Compliance Monitoring Reports and reported to the regulatory agencies.

Treatment system influent and effluent are sampled and analyzed per the requirements of the Compliance Monitoring Plan/Contingency Plan to ensure compliance with discharge requirements. The Building 854 OU GWTS influent and effluent results for the five-year review period were included in the semiannual Compliance Monitoring Reports and reported to the regulatory agencies. These reports can be accessed electronically at LLNL's Environmental Restoration Department electronic library web page at <http://www-erd/library>.

During the five-year review period (January 2008 to January 2013), the 854-SRC, 854-PRX and 854-DIS GWTSs operated in compliance with the Substantive Requirements for Wastewater Discharge with the following exception:

- Nitrate was detected at 47 mg/L in the February 9, 2010 effluent sample from 854-PRX. This is slightly above the nitrate discharge limit (45 mg/L) due to cold weather and shutdown duration that negatively affected bacterial nitrate reduction in the wetland biotreatment system.

The 854-SRC SVTS operated in compliance with San Joaquin Valley Air Pollution Control District air permit requirements.

Treatment system parameters such as pressure and flow are routinely recorded to anticipate potential mechanical problems and monitor system performance.

The major O&M activities for the Building 854 treatment systems include:

- Maintaining the particulate filters.
- Maintaining the misting tower and infiltration trench used to discharge treated ground water.
- Maintaining the wetland biotreatment system.
- Protecting the units from freezing in cold weather.
- Replacing spent GAC and resin.
- Replenishing vinegar used as carbon source for the wetland biotreatment system.

- Routinely inspecting and maintaining extraction well pumps, pipelines and flow meters.

The budgeted and actual environmental restoration costs for the Building 854 OU are tracked closely and are consistently within or near the allocated budget. Table 1 presents the actual costs for the last five fiscal years, 2008 through 2012.

4.4 Land Use Controls

Land use controls are restrictions or controls that are implemented to protect human health and the environment, such as restricting access or limiting activities at a contaminated site. Types of land use controls include:

- Institutional controls,
- Engineered controls, and
- Physical barriers.

The U.S. EPA (2010) defines institutional controls as non-engineered instruments, such as administrative and legal controls, that help to minimize the potential for human exposure to contamination and/or protect the integrity of a response action. Institutional controls are typically designed to work by limiting land or resource use or by providing information that helps modify or guide human behavior at a site. Institutional controls are a subset of land use controls. Institutional controls are divided into four categories:

1. Proprietary controls.
2. Governmental controls.
3. Enforcement and permit tools.
4. Information devices.

Proprietary controls are generally created pursuant to State law to prohibit activities that may compromise the effectiveness of a remedial action or restrict activities or future resource use that may result in unacceptable risk to human health or the environment, such as easements and covenants. Governmental controls impose restrictions on land use or resource use, using the authority of a government entity. Federal landholding agencies, such as DOE, possess the authority to enforce institutional controls on their property. At active federal facilities, such as LLNL Site 300, land use restrictions may be addressed in master plans, facility construction review processes, and digging permit systems. Enforcement and permit tools are legal tools, such as Federal Facility Agreements (FFAs), that limit certain site activities or require the performance of specific activities. Information devices provide information or notifications to local communities that residual or contained contamination remains onsite.

Land use controls also include engineering controls and physical barriers, such as fences and security guards, as means to protect human health by reducing or eliminating the hazard and/or the potential for exposure to contamination.

In this document, the term “land use controls” is used to encompass institutional controls, engineered controls, and physical barriers.

The land use controls and requirements described herein are only applicable to the Building 854 OU and associated contaminated environmental media that are being addressed through the CERCLA process. As required by the Site 300 Compliance Monitoring Plan, the

land use controls are reviewed annually using the Institutional Controls Monitoring Checklist. The land use/institutional controls checklist was reviewed and approved by the regulatory agencies and was presented in the 2009 Compliance Monitoring Plan. The inspection results are reported in the annual Site 300 Compliance Monitoring Reports.

Land use controls for the Building 854 OU are described in Table 2 that presents descriptions of: (1) the land use control objective and duration, (2) the risk necessitating these controls, and (3) the specific land use controls and implementation mechanisms used to prevent exposure to contamination at the Building 854 OU. Figure 8 shows the specific areas of the Building 854 OU where the land use controls have been maintained or implemented.

The land use control objectives and the risk necessitating these controls, the specific land use controls and implementation mechanisms used to prevent exposure to contamination at the Building 854 OU by objective, and the status of the land use controls are summarized below.

4.4.1. Building 854 OU Land Use Control Objectives

Land use control objectives were established for the Building 854 OU in the Site 300 ROD (DOE, 2008) to reduce risk and prevent exposure to contaminated environmental media. The risk drivers and associated land use controls identified for the Building 854 OU include:

1. **Risk Driver** - VOC concentrations exceed cleanup standards in onsite ground water. There is no ground water contaminants near the site boundary associated with this OU.

Land use control objectives:

- Prevent onsite water-supply use/consumption of contaminated ground water until ground water cleanup standards are met.

2. **Risk Driver** - Potential exposure to VOCs at depth in subsurface soil.

Land use control objective:

- Control excavation activities to prevent onsite worker exposure to contaminants in subsurface soil until it can be verified that concentrations do not pose an exposure risk to onsite workers.

3. **Risk Driver** - The baseline risk assessment identified a risk of 1×10^{-6} and 9×10^{-6} for onsite workers from inhalation of VOCs volatilizing from subsurface soil into indoor air at Buildings 854A and 854F, respectively and a risk of 1×10^{-5} for onsite workers from inhalation of VOCs volatilizing from subsurface soil into outdoor air in the vicinity of Buildings 854F.

Land use control objective:

- Prevent onsite site worker inhalation exposure to VOCs in indoor and outdoor air at Buildings 854A and 854F until annual risk re-evaluation indicates that the risk is less than 10^{-6} .

4. **Risk Driver** - Potential exposure to contaminated environmental media.

Land use control objective:

- Prohibit transfer of lands with unmitigated contamination that could cause potential harm under residential or unrestricted land use. In the event that Site 300 property with unmitigated contamination that could cause potential harm under residential or unrestricted land use is transferred in the future, DOE will execute a land use

covenant at the time of transfer in compliance with Title 22 California Code of Regulations Division 4.5, Chapter 39, Section 67391, and deed restrictions per CERCLA 120(h).

4.4.2. Building 854 OU Land Use Controls

This section discusses the land use controls including institutional controls, engineered controls, and physical barriers for the Building 854 that were established and are implemented to address the risk reduction objectives and their current status.

4.4.2.1. Prevent Onsite Water-supply Use/consumption of Contaminated Ground Water: Governmental Institutional Controls

DOE/LLNL has implemented multiple layers of protection (land use controls) to prevent the water-supply use or consumption of onsite contaminated ground water in the Building 854 area until ground water cleanup standards are met. The land use controls include:

- Dig Permit Process
- Work Induction Board Process

Governmental Institutional Controls Implementation Status

Dig Permit Process: A LLNL Dig Permit is required to drill and install any new onsite wells at Site 300. This permit process includes an evaluation of the proposed well location by the LLNL Environmental Analyst to determine if the proposed new water-supply well is located in an area of ground water contamination. If it is determined that the proposed water-supply well location is in a ground water contamination area, the Environmental Analyst works with the LLNL entity proposing the well installation and the LLNL Environmental Restoration Department to relocate the well to ensure ground water contaminants would not be drawn into the well before a dig permit is issued. During this five-year review period, there were no dig permit applications to drill and install new onsite water-supply wells within areas of onsite ground water contamination in the Building 854 OU.

Work Induction Board: Any proposed onsite well drilling activities are also submitted to the LLNL Work Induction Board, and are reviewed by the LLNL Environmental Restoration Department to ensure that new water-supply wells are not located in areas of ground water contamination. The Work Induction Board meets weekly to review new proposed work at Site 300 to ensure that work is conducted in conformance with the appropriate controls and includes the special concerns for work at Site 300 (i.e., environmental contamination).

During this five-year review period, there were no proposals brought to the Work Induction Board to drill and install new onsite water-supply wells within areas of onsite ground water contamination in the Building 854 OU.

4.4.2.2. Control Onsite Excavation Activities: Governmental Institutional Controls

The land use controls that have been implemented to control excavation activities to prevent onsite worker exposure to contaminants in subsurface soil until it can be verified that concentrations do not pose an exposure risk to onsite workers include:

- Dig Permit Process
- Work Induction Board Process

Governmental Institutional Controls Implementation Status

Site 300 implements multiple layers of protection to prevent onsite worker exposure to contaminants in subsurface soil: Dig Permit and Work Induction Board processes.

Dig Permit Process: A LLNL Dig Permit is required to conduct any ground disturbing activities at Site 300, including activities that involve the excavation of soil and/or rock. This permit process includes an evaluation of the proposed location for the ground disturbing/excavation activity by the LLNL Environmental Analyst to determine if it is located in an area of soil/rock contamination. The Environmental Analyst works with the LLNL entity proposing the ground disturbing/excavation activity to determine if the activity can be moved. If the work plans cannot be modified to move excavation activities outside of areas of soil contamination, LLNL Environmental Health & Safety personnel evaluate the potential hazards and identify the necessary controls to be implemented prior to the start of work. During this five-year review period, there were no dig permit applications for excavation or construction activities at the Building 854 OU.

Work Induction Board: Any proposed excavation activities are submitted to the LLNL Work Induction Board, and are reviewed by LLNL Environmental Restoration Department to prevent potential exposure to VOCs at depth in subsurface soil. The Work Induction Board meets weekly to review new proposed work at Site 300 to ensure that work is conducted in conformance with the appropriate controls and includes the special concerns for work at Site 300 (i.e., environmental contamination).

During this five-year review period, there were no proposals brought to the Work Induction Board or as part of the dig permit process conduct excavation activities within areas of contamination in the Building 854 OU.

4.4.2.3. Prevent Onsite Site Worker Inhalation Exposure to VOCs inside Building 854A and 854F

Pre-remediation risks of 1.0×10^{-6} and 9.3×10^{-6} were calculated for onsite workers from inhalation of VOCs volatilizing from subsurface soil into indoor air at Buildings 854A and 854F, respectively and a pre-remediation risk of 1×10^{-5} was calculated for onsite workers from inhalation of VOCs volatilizing from subsurface soil into outdoor air in the vicinity of Buildings 854F.

These risks were successfully mitigated by 2004 and 2005 (prior to this review period) through ground water and soil vapor extraction and treatment and building demolition. Therefore this land use control is no longer needed (Section 6.4.2).

4.4.2.4. Prohibit Transfer of Lands with Unmitigated Contamination: Proprietary Controls

Land use controls have been implemented to prohibit the transfer of Site 300 property or portions thereof with unmitigated contamination that could cause potential harm under residential or unrestricted land use, as required in the Site 300 ROD. The land use control and implementation status is described in more detail below.

Proprietary Controls Implementation Status

To prevent the potential exposure to contaminated waste and/or environmental media, the Site 300 FFA and Site 300 ROD contain provisions that assure DOE will not transfer lands with

unmitigated contamination that could cause potential harm. In the event that the Site 300 property is transferred in the future, DOE will execute a land use covenant at the time of transfer in compliance with Title 22 CCR, Division 4.5, Chapter 39, Section 67391.1 as specified in the Site 300 ROD, and will implement deed restrictions per CERCLA 120(h). The Site 300 FFA and ROD have not been modified during this five-year review period, and these provisions remain as originally stated in these documents.

Development will be restricted to industrial land usage. These restrictions will remain in place until and unless a risk assessment is performed in accordance with then current U.S. EPA risk assessment guidance and the DOE, U.S. EPA, DTSC, and RWQCB agree adequately shows that no unacceptable risk for residential or unrestricted land use is present.

LLNL Site 300 remains an active DOE facility, and DOE has not proposed any plans to transfer any Site 300 land for residential, unrestricted, or non-DOE industrial land use during the five-year review period. Therefore, it has not been necessary to execute a land use covenant or deed restrictions. These institutional controls will be implemented if and when the property or a portion thereof is transferred in accordance with the requirements of the Site 300 ROD, Title 22 CCR Division 4.5, Chapter 39, Section 67391.1, and CERCLA 120(h).

4.4.2.5. Other Controls: Physical Barriers

The fences surrounding Site 300, signs, and security forces control and restrict access to Site 300; thereby preventing the inadvertent exposure by members of the public to contamination at Site 300. The LLNL Protective Services Force conducts routine inspections of the fences surrounding Site 300 to ensure they are intact. A member of the security force mans the entrance gate to Site 300 during hours when the front gate is open, and a DOE-issued security badge is required to gain entrance to the site. The site gates are closed and locked after 6 pm, and a security force member remains onsite overnight. Members of the public must apply for and obtain security badges and be escorted to access the site.

The physical barriers to control and restrict access are effective in preventing inadvertent exposure by members of the public to contamination at Site 300, and therefore are protective of human health.

4.4.3. Summary of the Status of Building 854 Land Use Controls

Because there is no existing offsite ground water contamination in this OU and baseline inhalation risks have been mitigated, land use controls are required to: (1) prevent drilling of an onsite water-supply well in contaminated ground water above MCLs and (2) control excavation activities to prevent onsite worker exposure to contaminants in subsurface soil. The review of the land use controls for the Building 854 for this five-year review period determined that these controls are effective for preventing exposure to contaminated media.

DOE will implement, maintain, and enforce the land use controls for the Building 854 OU for as long as necessary to keep the selected remedy protective of human health and the environment.

5. Progress Since Last Review

This section describes the Protectiveness Statement and recommendations and follow-up actions from the 2008 Building 854 OU Five-Year Review. It also describes the status of the actions recommended in this previous review.

5.1. Protectiveness Statement from Last Review

The 2008 Five-Year Review Protectiveness Statement:

“The remedy at the Building 854 OU is expected to be protective of human health and the environment upon completion (i.e., when cleanup standards are achieved) for the site’s industrial land use. In the interim, the remedy protects human health because exposure pathways that could result in unacceptable risk to onsite workers are being controlled by the implementation of institutional controls, the Health and Safety Plan, and the Contingency Plan.

The cleanup standards for Building 854 OU ground water are drinking water standards. Because drinking water standards do not differentiate between industrial and residential use, the ground water cleanup remedy will be protective under any land use scenario upon completion.

The cleanup standards for VOCs in subsurface soil are to reduce concentrations to mitigate risk to onsite workers and prevent further impacts to ground water to the extent technically and economically feasible. Because some VOCs may remain in subsurface soil following the achievement of these cleanup standards, a land use control prohibits the transfer of lands with unmitigated contamination that could cause potential harm under residential or unrestricted land use. This prohibition is included in the Site-Wide ROD. This prohibition will remain in place until and unless a risk assessment is performed in accordance with current U.S. EPA risk assessment guidance and is agreed by the DOE, the EPA, the DTSC, and RWQCB as adequately showing no unacceptable risk for residential or unrestricted land use.”

5.2. Recommendations and Follow-up Actions from the 2008 Five-Year Review

The following recommendations were developed during the Five-Year Review process in 2008:

1. Increase pumping 854-SRC GWTS extraction well W-854-2218 to maximize yield and increase source area capture. This may include replacing the pump, and handling additional effluent discharge by constructing more misting towers or by reinjecting the effluent into a well upgradient of the source area. If the additional effluent were to be reinjected, a carbon source (e.g. lactate) would need to be added to the injected effluent to facilitate *in situ* bioremediation of nitrate.
2. Discontinue extraction from 854-SRC GWTS well W-854-17 due to extremely low yield.
3. Monitor total VOC concentrations in monitor well W-854-09. If concentrations remain above MCLs and show an increasing trend over time, convert well W-854-09 to an 854-SRC GWTS extraction well. However, W-854-09 would not be considered for conversion to an extraction well until after the flow rate and hydraulic capture of nearby extraction wells W-854-2218 (Recommendation 1) and W-854-03 (Recommendation 5) have been increased and sufficient time has been allowed for performance evaluation.

This decision will most likely be made during preparation of the next five-year review for this OU. Any changes will be documented in the Recommendations and Follow-up Actions Section.

4. Continue operation of 854-SRC SVTS extraction wellfield with periodic rebound tests conducted in the future as specified in the SVE system shutoff criteria.
5. Increase the pumping rate of 854-PRX extraction well W-854-03 to maximize yield and increase hydraulic capture. This may include replacing the pump and handling additional discharge by increasing the size and efficiency of the biotreatment system and/or adding misting towers to facilitate the increased discharge volume from this facility.
6. Monitor perchlorate concentrations in well W-854-45. DOE will evaluate data from this well to attempt to resolve some unusual temporal trends in ground water levels and perchlorate concentrations to confirm that they are representative of subsurface conditions. If this evaluation confirms that perchlorate concentrations detected in well W-854-45 are representative of subsurface conditions and that perchlorate concentrations persist above the 6 µg/L MCL cleanup standard, DOE will discuss *in situ* remedial technologies for perchlorate in the immediate vicinity of this well with the regulatory agencies. Any change to the remedy would be documented in an Explanation of Significant Differences (ESD).
7. Evaluate remedial options to remediate perchlorate in the vicinity of well W-854-1823. For example, DOE may evaluate *in situ* bioremediation by conducting a treatability study that would include hydraulic testing to determine the injection capacity of well W-854-1823, and the injection of a reagent (i.e., sodium lactate) to encourage microbial reduction of perchlorate to benign by-products. Any change to the remedy would be documented in an ESD.
8. If perchlorate concentrations continue to increase in wells W-854-45 and W-854-1823, additional investigation of the source and extent will be conducted. However, it is important to note that any investigation of extent of perchlorate ground water contamination would be limited due to steep topography and the presence of an ecological preserve in the area of these wells, and by restrictions on drilling in surface water drainage ways.
9. Continue to evaluate MNA as a remedial approach for nitrate in the downgradient proximal and distal areas of the Building 854 OU. *In situ* bioremediation of nitrate is recommended for the source area, such as injecting both the nitrate-bearing effluent and a carbon source (e.g., sodium lactate) to facilitate *in situ* biodegradation. Any change to the remedy would be documented in an ESD.

No other follow-up actions were identified related to the 2008 Five-Year Review.

5.3. Results of Implemented Actions

The status of actions taken in response to the recommendations listed in Section 5.2 are as follows:

1. Recommendation #1 was completed. The pump in W-854-2218 was replaced in April 2010 increasing average flow from 1 gpm (2009 average flow) to 2.6 gpm (2010

average flow). The 2011 average flow was 1.2 gpm. The pump was replaced again in February 2012. Current (2012 average) flow is 2.7 gpm.

2. Recommendation #2 was completed. In October 2010, W-854-17 was taken offline and converted to a monitor well.
3. Recommendation #3 evaluation was completed. While TCE concentrations in monitor well W-854-09 have remained above the MCL cleanup standard of 5 µg/L and have slightly fluctuated since 2008, overall TCE concentrations have remained relatively stable (Figure 9). TCE concentrations increased slightly from a 2008 maximum of 9.3 µg/L to a 2009 maximum of 14 µg/L; then remained relatively stable (fluctuating from 6.3 to 11 µg/L). The October 2012 TCE concentration was 8.9 µg/L. In addition, further evaluation of well W-854-09 determined that it was not capable of sustaining the flow necessary for effective ground water extraction. Therefore, while DOE/NNSA will continue to monitor VOC concentrations in this well, it will not be converted to an extraction well.
4. Recommendation #4 evaluation was completed. Vapor extraction has continued from 854-SRC SVTS well W-854-1834 during the five-year review period. The October 2012 TCE vapor concentration was 0.31 parts per million on a volume per volume basis (ppm_{v/v}). Continued vapor rebound testing has also occurred and is described Section 6.4.1 below. Although the TCE vapor concentrations are typically low, including after rebound periods, significant TCE mass is being removed from the Building 854 source area. DOE/NNSA plans to continue operating the 854-SRC SVTS until vapor concentrations remain below reporting limits after extended shutdown periods and SVE shutoff criteria have been met. Because this evaluation is part of the on-going remediation evaluation, it was not retained as a recommendation.
5. Recommendation #5 evaluation is on-going. The pumping rate of 854-PRX extraction well W-854-03 is currently constrained by the limited capacity of the nitrate biotreatment system and the infiltration trench. While an evaluation of options for facility and discharge method modifications was conducted during the five-year review period, evaluation progress was hampered by implementability constraints. These constraints include restrictions due to the presence of critical habitat for special status species in the area that limit effluent discharge options. Consultation with the U.S. Fish and Wildlife Service may be required prior to selecting and implementing an alternate discharge method. In addition, there may not be sufficient capacity in the effluent infiltration trench to accommodate significant increased flow from W-854-03, therefore other effluent discharge options were/are being evaluated. Other implementability constraints include the availability of power necessary for increasing flow and issues associated with excessive nitrate-loading of treatment media. During the next five years, DOE/LLNL will continue to evaluate options for modifying the treatment facility and effluent discharge method to accommodate increased flow from W-854-03 (Section 9, Recommendation #2).
6. Recommendation #6 was completed. Within the last five years, perchlorate concentrations in well W-854-45 increased from 9.8 µg/L in 2008 to a maximum of 15.2 µg/L in 2011, but then decreased since 2011 to an October 2012 concentration of 10 µg/L. It was confirmed that perchlorate concentrations were representative of

subsurface conditions. While perchlorate concentrations in well W-854-45 remain slightly above the 6 µg/L MCL cleanup standard and showed some increases during the five-year review period, concentrations at the end of the five-year review period were essentially the same as in the beginning of the five-year review period. If monitoring over the next five years indicates that perchlorate concentrations in this well stabilize and remain above the 6 µg/L MCL cleanup standard or show increasing trends, DOE/LLNL will discuss implementing remedial measures in or near this well with the regulatory agencies (Section 9, Recommendation #4).

7. Recommendation #7 evaluation is on-going. While remedial options were identified (i.e., *in situ* and *ex situ* bioremediation), a treatability study was not performed during the five-year review period because perchlorate concentrations in well W-854-1823 have continued to show a decreasing trend both from its historical maximum (27 µg/L in 2003) and during the five-year review period. Perchlorate concentrations in this well decreased from 22 µg/L in 2008 to 13 µg/L in October 2012. For this reason, DOE will continue to monitor perchlorate concentrations in well W-854-1823 during the next five years. If monitoring over the next five years indicates that perchlorate concentrations in this well stabilize and remain above the 6 µg/L MCL cleanup standard or show increasing trends, DOE/LLNL will discuss implementing remedial measures in or near this well with the regulatory agencies (Section 9, Recommendation #4).
8. Recommendation #8 evaluation was completed. The source of perchlorate detected in well W-854-45 was determined to be activities conducted at or near Building 858 drop tower complex, located approximately 185 ft northeast and upgradient of this well. Although HE compounds have not been detected in this well, the perchlorate is thought to be derived from HE materials (as ammonium perchlorate) contained in test devices used at the drop tower. The source of perchlorate detected in well W-854-1823 is most likely the former rinse water disposal lagoon located just south of Building 855B and upgradient of this well. While in use, rinse water in the lagoon may have contained minor amounts of HE particulates (including ammonium perchlorate). As there are no other known activities that were conducted between Building 855B and well W-854-1823, the perchlorate detected in this well is likely a detached plume that has migrated downgradient from the 855 former lagoon area. (No HE compounds have been detected in this well.) As discussed in #7 and #8 above, while perchlorate concentrations in wells W-854-45 and -1823 are slightly above the 6 µg/L MCL cleanup standard, concentrations trends are generally stable to decreasing.
9. Recommendation #9 evaluation is on-going. A study was conducted to evaluate MNA as a remedial approach for nitrate in the downgradient proximal and distal areas of the Building 854 OU. The study involved the analysis of ground water and spring samples from the Building 854 area to evaluate the capacity for microbial denitrification by measuring the stable isotopic composition of nitrate (delta nitrogen-15 [$\delta^{15}\text{N}$]-nitrate [NO_3] and delta oxygen-18 [$\delta^{18}\text{O}$]- NO_3) and excess dissolved nitrogen (N_2) (greater than atmospheric equilibrium) in ground water. As microbial denitrification proceeds, the isotopic composition of the remaining nitrate becomes more enriched in the heavier $\delta^{15}\text{N}$ - NO_3 and $\delta^{18}\text{O}$ - NO_3 isotopes because bacteria preferentially utilize lighter isotopes. Concurrently, the mass of excess dissolved nitrogen, N_2 , the end product, increases.

The study involved the measurement of $\delta^{15}\text{N-NO}_3$ and $\delta^{18}\text{O-NO}_3$ and excess dissolved N_2 in samples from 18 wells screened in the Qls/Tnbs₁ (3 wells), Tnbs₁/Tnsc₀ (13 wells), Tnsc₀ (1 well), and Tmss (1 well) HSUs and 2 springs. The presence of measurable excess N_2 relative to nitrate concentration indicates some low level denitrification in the Tnbs₁/Tnsc₀ HSU. The general decrease in nitrate concentration along the ground water flow path is likely a combination of some denitrification coupled with dispersion and diffusion. Although the Qls/Tnbs₁ and the Tnsc₀ HSU wells did not exhibit conclusive evidence of denitrification, Tmss HSU well W-854-1731 exhibited strong evidence for denitrification, including enriched nitrate isotopic composition, low nitrate concentration, and a high proportion of excess N_2 relative to nitrate concentration. DOE/NNSA will conduct further analysis to determine whether the Tmss HSU exhibits a widespread assimilative capacity for nitrate reduction. Additional details of the nitrate MNA study are presented in Attachment A.

5.4. Status of Other Prior Issues

There are no other prior issues.

6. Five-Year Review Process

6.1. Notification of Review/Community Involvement

The report will be placed in the Administrative Record file and the Information Repositories located in the LLNL Discovery Center in Livermore, California and in the Tracy Public Library in Tracy, California. Notice of its initiation and completion will be placed in two publications: *The Tracy Press* and *San Joaquin Herald*. The initial notice was published in *The Tracy Press* and *San Joaquin Herald* on XXXX (to be filled in after the draft is published). Completed documents can also be accessed electronically at LLNL's Environmental Restoration Department electronic library web page at <http://www-erd/library/> or the Environmental Community Relations web page at <http://www-envirinfo.llnl.gov>.

The draft, draft final, and final Five-Year Review is also submitted to the community action group, Tri-Valley Communities Against a Radioactive Environment, for review.

6.2. Identification of Five-Year Review Team Members

The Five-Year Review of the Building 854OU at LLNL Site 300 was led by Claire Holtzapple, Site 300 Remedial Project Manager for the DOE/NNSA-Livermore Field Office. The following team members assisted in the review:

- Leslie Ferry, Program Leader, LLNS.
- Valerie Dibley, Deputy Program Leader, LLNS.
- Vic Madrid, Hydrogeology Team Leader, LLNS.
- John Valett, Hydrogeologist, Weiss Associates.
- Mark Buscheck, Hydrogeologist, Weiss Associates.
- Michael Taffet, Hydrogeologist, LLNS.

- John Radyk, Hydrogeologist, Weiss Associates.

6.3. Document Review

This Five-Year Review consisted of examining relevant project documents and site data:

- Final Site-Wide Remedial Investigation for Lawrence Livermore National Laboratory Site 300 (Webster-Scholten et al., 1994).
- Final Site-Wide Feasibility Study for Lawrence Livermore National Laboratory Site 300 (Ferry et al., 1999).
- Interim Site-Wide Record of Decision for Lawrence Livermore National Laboratory Site 300 (U.S. DOE, 2001).
- Characterization Summary Reports for the Site 300 Building 854 Operable Unit (Ferry and Kearns, 2002 and Ziagos and Reber-Cox, 1998).
- Site-Wide Record of Decision for Lawrence Livermore National Laboratory Site 300 (U.S. DOE, 2008).
- Remedial Design Work Plan for Interim Remedies at Lawrence Livermore National Laboratory Site 300 (Ferry et al., 2001b).
- Interim Remedial Design for the Building 854 Operable Unit at Lawrence Livermore National Laboratory Site 300 (Daily et al., 2003).
- Five-Year Review Report for the Building 854 Operable Unit Lawrence Livermore National Laboratory Site 300 (Dibley et al., 2008a).
- Site-Wide Remediation Evaluation Summary Report for Lawrence Livermore National Laboratory Site 300 (Ferry et al., 2006).
- Compliance Monitoring Plan/Contingency Plan for Environmental Restoration at Lawrence Livermore National Laboratory Site 300 (Dibley et al., 2009a).
- Semi-annual Site-Wide Compliance Monitoring Reports (2008-2012) that include evaluations of remediation progress in the Building 854 OU (Dibley et al., 2009b, 2009c, 2010a, 2010b, 2011b, 2011c; 2012a, 2012b, 2013; and LLNL 2008).

This Five-Year Review evaluates subsurface contaminant concentration and remediation system performance data collected through the calendar year 2012.

6.4. Data Review and Evaluation

A review and evaluation were conducted of data collected during this review period to determine progress in: (1) remediating the vadose zone to shutdown criteria (Section 6.4.1), (2) remediating ground water to meet cleanup standards (Section 6.4.2), and (3) mitigating risk to onsite workers (Section 6.4.3).

6.4.1. Vadose Zone Remediation Progress

The 854-SRC SVTS extracts vapor from SVE well W-854-1834 and has been operating continuously since November 2005, except for intermittent periods due to weather-related delays or when rebound testing or electrical work was performed. SVE well W-854-1834 is located in the Building 854 TCE source area and screened exclusively in the vadose zone. The historic

maximum TCE vapor concentration was 4.4 ppm_{v/v} (November 2005). The 2012 maximum TCE vapor concentration was 0.44 ppm_{v/v} (February). The system's operational history (monthly vapor flow in standard cubic feet [scf]) and historical TCE vapor concentrations in ppm_{v/v} are presented on Figure 10.

The system currently operates at a flow rate of approximately 50 scfm. At SVTS startup, the initial TCE concentrations were in the 3.7 to 4.4 ppm_{v/v} range. TCE mass removed from vapor by the 854-SRC SVTS is presented on Figure 11. To date, the facility has removed 11.9 kilograms (kg) of TCE from soil vapor. Substantially more TCE mass (approximately twice as much) is being removed by soil vapor extraction than by ground water extraction in this area. This TCE is likely volatilizing from vadose zone sources beneath the Building 854 source area and vapors from the underlying dissolved TCE plume in Tnbs₁/Tnsc₀ ground water.

Since the last Five-Year Review, a series of system operations, rebound tests, and sampling events were conducted. Figure 10 presents the results of rebound testing conducted during both the previous Five-Year Review (Rebound Tests 1-3) and this Five-Year Review (Rebound Tests 4-7). System operations, rebound tests and sampling events results for this Five-Year Review are as follows:

- The SVTS was shut down from April 17, 2008 to July 9, 2008 to allow TCE concentrations in soil vapor to rebound. The TCE concentration in a soil vapor sample collected just prior to shutting off the system was 0.32 ppm_{v/v}.
- July 9, 2008: After the system had been off for three months, rebound sampling (Rebound Test 4, Figure 10) was conducted. The system was restarted and a vapor sample was collected from the well W-854-1834 10 minutes after restart and analyzed for TCE. The soil vapor sample contained 0.82 ppm_{v/v} of TCE, indicating that rebound had occurred during the system shutdown. The system was again shut down from late in the day on July 9 to July 14 due to extreme heat. An additional vapor sample was collected on July 14 after restarting the system; the TCE vapor concentration was 0.085 ppm_{v/v}.
- July 14, 2008 to November 17, 2010: The system ran continuously during this time period, except from December 16, 2009 to February 3, 2010, when it was off to protect against damage potentially caused by freezing temperatures. By October 2010, TCE vapor concentrations had declined to 0.035 ppm_{v/v}.
- November 17, 2010 to July 11, 2011: The system was offline initially to protect against potential damage caused by freezing temperatures, then for construction of a new condensate knockout skid, and then for a vapor rebound test. By May 31, 2011, TCE concentrations had rebounded to 0.12 ppm_{v/v} (Rebound Test 5, Figure 10) at which time, vapor extraction re-commenced. After one week of operation, on July 7, 2011, TCE concentrations were measured at 0.42 ppm_{v/v}. At this time, the system was again shut down for further vapor rebound evaluation. A vapor sample was collected on July 11, 2011 (Rebound Test 6, Figure 10) and contained 0.46 ppm_{v/v} of TCE. At this time, vapor extraction recommenced.
- July 11 to November 28, 2011: The SVTS system ran continuously.
- November 28, 2011 to February 10, 2012: The system was shut down after instrumentation issues were identified during the previous system restart. After restart in February 2012, TCE concentrations were measured at 0.44 ppm_{v/v} on February 13, 2012

(Rebound Test 7, Figure 10). Throughout the remainder of 2012, the system ran continuously with TCE concentrations ranging from 0.21 to 0.31 ppm_{v/v}.

Although the TCE vapor concentrations are typically low, including after rebound periods, significant mass has been removed from the Building 854 source area during the seven years of intermittent operation of the SVTS system due to the high flow. SVE well W-854-1834 is removing residual TCE mass that exists in the vadose zone in addition to TCE that is volatilizing from the underlying dissolved plume in the ground water. DOE/NNSA plans to continue operating the 854-SRC SVTS until vapor concentrations remain below reporting limits after extended shutdown periods and SVE shutoff criteria have been met.

6.4.2. Ground Water Remediation Progress

The progress of ground water remediation in the Building 854 OU was evaluated by:

- Reviewing ground water COC mass removal data (Figures 11 and 12).
- Reviewing temporal COC concentration trends in ground water.
- Comparing 2007 and 2012 ground water COC concentrations and spatial distribution (Figures 13 and 14).
- Evaluating extraction wellfield capture zones (Figures 7, 15 and 16).

The results of this evaluation for the Building 854 OU ground water COCs during this five-year review period are discussed in the following subsections: contaminant concentrations and distribution (Section 6.4.2.1), contaminant remediation and mass removal (Section 6.4.2.2), and capture zone analysis (Section 6.4.2.3).

6.4.2.1. Contaminant Concentrations and Distribution

At the Building 854 OU, TCE and perchlorate are the primary COCs in ground water; nitrate is a secondary COC. For the purposes of compliance monitoring, ground water COCs were designated as primary or secondary in the Site 300 Compliance Monitoring Plan/Contingency Plan. Primary COCs are those that generally exhibit: (1) higher migration rates than secondary COCs; (2) larger horizontal and vertical extent of contamination than secondary COCs; and (3) any other contaminant- or area-specific consideration that indicates that a more frequent sampling frequency is appropriate (e.g., a highly toxic contaminant). Primary COCs are generally monitored more frequently (semi-annually) than secondary COCs (annually).

VOC, perchlorate, and nitrate contamination in Building 854 OU ground water occurs primarily in the Tnbs₁/Tnsc₀ HSU (Figures 15, 16, and 17). Some TCE and nitrate have also been detected in the perched ground water in the Tnbs₁ portion of the Qls/Tnbs₁ HSU, near the 854-SRC area (Figure 12). No contamination has been detected above reporting limits in the Qls portion of the Qls/Tnbs₁ HSU or in the Tnsc₀ HSU. No contamination above MCL cleanup standards has been detected in the deeper Tmss HSU. VOC, perchlorate and nitrate concentrations, distribution, and remediation are discussed in Sections 6.4.2.1.1 through 6.4.2.1.3.

6.4.2.1.1. VOC Concentrations, Distribution, and Remediation

TCE is a primary COC and continues to be detected in Building 854 OU ground water at concentrations exceeding the 5 µg/L MCL cleanup standard. Although cis-1,2-DCE is not a COC, very low concentrations of this analyte are detected in samples from monitor wells W-854-11 and W-854-17 and extraction wells W-854-2139 and W-854-2218 (Figure 15).

Overall, VOC concentrations in Building 854 ground water have decreased by two orders-of-magnitude from a historical pre-remediation maximum of 2,900 µg/L in 1997 to a maximum concentration of 100 µg/L in the second semester of 2012. A hydrogeologic cross-section depicting the vertical distribution of total VOCs in the Building 854 OU HSUs is presented on Figure 5. VOC concentrations are discussed by HSU by increasing depth below.

Qls/Tnbs₁ HSU

VOCs have not been detected in wells screened in the Qls portion of the Qls/Tnbs₁ HSU since 1999. TCE has been detected in wells screened in the shallow perched ground water in the Tnbs₁ portion of the Qls/Tnbs₁ HSU that is situated above the Tnbs₁/Tnsc₀ HSU. The historic maximum TCE concentration of 41 µg/L was detected in a ground water sample collected from monitor well W-854-10 in July 2010, that is screened in the Tnbs₁ portion of the Qls/Tnbs₁ HSU. This well is located in the 854-SRC area (Figure 3). By October 2012, TCE concentrations in this well had decreased to 14 µg/L. The long-term TCE concentrations in ground water from this well exhibit intermittent fluctuations but have ranged between 8 and 14 µg/L since June 2010. The recent intermittent increases and declines in TCE concentrations in this well roughly correlate with declines and increases in water elevations in excess of 1 foot over a 3 month period suggesting that TCE concentrations in this thin perched water-bearing zone are diluted by intermittent recharge events. While low TCE concentrations (<1 µg/L) were detected twice in Tnbs₁ monitor well W-854-14, located near Building 858, TCE concentrations have been below the 0.5 µg/L reporting limit since 2000. Cis-1,2-DCE has never been detected above the reporting limit in wells screened in the Tnbs₁ portion of the Qls/Tnbs₁ HSU.

Tnbs₁/Tnsc₀ HSU

Overall, VOC concentrations in Tnbs₁/Tnsc₀ HSU ground water have decreased by two orders-of-magnitude, from an historic maximum of 2,900 µg/L in 1997 to 93 µg/L in July 2012. A total VOC isoconcentration contour map and individual VOC concentrations in the Tnbs₁/Tnsc₀ HSU are shown on Figure 15.

The historic maximum concentration of cis-1,2-DCE (19 µg/L, 2001) and 2012 maximum concentration (3.4 µg/L, October) were detected in Tnbs₁/Tnsc₀ HSU monitor well W-854-17. While cis-1,2-DCE concentrations in this well have exceeded the 6 µg/L MCL cleanup standard in the past, current (2012) concentrations are below the cleanup standard. Cis-1,2-DCE has also been detected in Tnbs₁/Tnsc₀ HSU wells W-854-11, W-854-2139 and W-854-2218 at concentrations ranging between 4.3 and 0.65 µg/L, all below its 6 µg/L MCL cleanup standard.

Figure 13 shows a comparison of the extent of the total VOC plumes and concentrations of individual VOCs in the Tnbs₁/Tnsc₀ HSU in 2007 and 2012. Two VOC plumes have been identified in the Tnbs₁/Tnsc₀ HSU: a northern plume and a less extensive southern plume.

The northern plume encompasses the 854-SRC and 854-PRX areas. Figure 13 shows the following changes regarding the northern extent of VOCs impacting Building 854 ground water during the five-year review period:

- The extent of the plume with concentrations above the 0.5 µg/L reporting limit has remained relatively stable over time (and since remediation began in 1999).
- The portion of the northern VOC plume with concentrations greater than 10 µg/L has been reduced by remediation.

- The portion of the northern VOC plume with concentrations greater than 50 µg/L has been reduced by remediation and is currently limited to the immediate vicinity of the 854-SRC area.
- The portion of the northern VOC plume with concentrations exceeding 100 µg/L has been completely remediated (since remediation began in 1999).

The northern plume is separated from the southern plume by a region where monitoring of two wells located in the area (W-854-1822 and W-854-1902) has not detected VOC concentrations above the 0.5 µg/L reporting limit since monitoring began in these wells in 2002.

The southern plume encompasses the 854-DIS area and the former water-supply Well 13 (Figure 15). Figure 13 shows the following changes regarding the southern extent of VOCs impacting Building 854 ground water during the five-year review period:

- The extent of the plume with concentrations above the 0.5 µg/L reporting limit has remained relatively stable over time.
- Three area wells have seen a reduction in VOCs (all TCE): W-854-2139 from 41 to 27 µg/L; W-854-07 from 40 to 32 µg/L; and W-854-06 from 1.5 to 0.6 µg/L.
- Two springs south of and downgradient of the southern plume have had maximum VOC concentrations of 0.9 µg/L (Spring 10, October 2011) and 2.8 µg/L (Spring 11, October 2011). A nearby well in the same area (W-854-45) has never had detectable VOCs since it was first sampled in 2000.

Tnsc₀ HSU

VOCs have never been detected in Tnsc₀ HSU ground water.

Tmss HSU

TCE was detected once in Tmss HSU ground water at a concentration of 0.62 µg/L in 1996, but has not been detected above the 0.5 µg/L reporting limit since that time. Cis-1,2-DCE has never been detected above the reporting limit in Tmss HSU ground water.

6.4.2.1.2. Perchlorate Concentrations, Distribution, and Remediation

Perchlorate has been detected in Building 854 OU ground water at concentrations exceeding the 6 µg/L MCL cleanup standard and is identified as a primary COC. In the 2008 Building 854 Five-Year Review, perchlorate was a secondary COC and re-designated to a primary COC in the revised 2009 Compliance Monitoring Plan/Contingency Plan. A hydrogeologic cross-section depicting the vertical distribution of perchlorate in the Building 854 OU HSUs is presented on Figure 6.

During 2012, perchlorate was not detected in ground water samples from any well screened in the Qls/Tnbs₁ HSU. In October 2010, 6.1 µg/L of perchlorate was reported in the sample from well W-854-15 that is screened in the Qls portion of the Qls/Tnbs₁ HSU. However, perchlorate was not detected at concentrations above the 4 µg/L reporting limit in samples collected from this well in the first semester 2010 sample, or in subsequent samples collected in 2011 and 2012.

Perchlorate has been detected in Building 854 OU ground water at concentrations exceeding the 6 µg/L MCL cleanup standard in the Tnbs₁/Tnsc₀ HSU. The distribution of perchlorate in Tnbs₁/Tnsc₀ HSU ground water observed during 2012 is similar to its extent in previous years. A perchlorate isoconcentration contour map for the Tnbs₁/Tnsc₀ HSU is presented on Figure 16.

Perchlorate concentrations in Tnbs₁/Tnsc₀ HSU ground water have decreased by approximately 50% from a historic maximum of 27 µg/L in 2003 to a 2012 maximum of 13.4 µg/L (May), both detected in monitor well W-854-1823 (located downgradient of the 854-PRX facility) (Figure 18). The five-year review period maximum of 16.6 µg/L (2008) was also detected in this well signifying a general decreasing trend over time.

Perchlorate has not been detected above the 4 µg/L reporting limit in ground water samples from the Tnsc₀ and Tmss HSUs.

Figure 14 shows a comparison of the extent of the perchlorate plume from 2007 to 2012. Figure 14 shows that since 2007: (1) the portion of the central perchlorate plume with concentrations greater than 18 µg/L has been completely remediated; (2) the portions of the central perchlorate plume with concentrations greater than 12 µg/L and 6 µg/L have been reduced by remediation; and (3) the extent of the northern and southern perchlorate plumes have changed little.

6.4.2.1.3. Nitrate Concentrations, Distribution, and Remediation

Nitrate has been detected in Building 854 OU ground water at concentrations exceeding the 45 µg/L MCL cleanup standard and is identified as a secondary COC. During 2012, ground water samples from five wells (Figures 19 and 17) exceeded the 45 mg/L MCL cleanup standard. The wells with nitrate concentrations exceeding the cleanup standard are located near 854-SRC and Building 858. The maximum 2012 and historic nitrate concentrations occurred in samples from the Building 858 area Qls/Tnbs₁ HSU well W-854-14 at 230 mg/L and 270 mg/L (2009), respectively.

Nitrate concentrations for all wells in the Building 854 OU remain stable or slightly decreasing with the exception of Tnbs₁/Tnsc₀ HSU well W-854-45, located near Building 858, which exhibits a slightly increasing trend. The nitrate concentration in well W-854-45 reached the 45 mg/L MCL in May 2009 and the most recent result from May 2012 is 48 mg/L.

Qls/Tnbs₁ HSU well W-854-05, yielded the highest nitrate concentration in the 854-SRC area at 59 mg/L. Since 1998, ground water nitrate at this well has consistently ranged between 42 and 63 mg/L. The other two wells yielding samples in excess of the cleanup standard, W-854-02 (extraction well) and W-854-2611, with 54 and 46 mg/L, respectively, are screened in the deeper Tnbs₁/Tnsc₀ HSU. The historic maximum nitrate concentration detected in Tnbs₁/Tnsc₀ HSU ground water, is 81 mg/L (monitor well W-854-08, 1998) and the five-year review period maximum is 60 mg/L (monitor well W-854-05, 2009). The distribution of nitrate in the Tnbs₁/Tnsc₀ HSU in the distal area remains low and essentially unchanged during the five-year review period. Nitrate was not detected above its MCL cleanup standard in the sample from monitor well W-854-10, which is screened in the perched Tnbs₁ water-bearing zone near the VOC source area.

Nitrate concentrations in samples collected from the Tnsc₀ and Tmss HSUs are below the cleanup standard and well within the range of natural background levels.

Samples of ground water from the Building 854 OU were analyzed for nitrate isotope and excess nitrogen analysis in 2002, 2007 and 2012. The results of these analyses are documented in Attachment A of this report. No ground water samples from Tnbs₁/Tnbs₀ HSU wells exhibited isotopic enrichment indicative of denitrification, although samples from several of the wells contained measureable excess nitrogen (N₂). Only one well, Tmss HSU well W-854-1731, yielded a sample exhibiting significant isotopic enrichment and excess N₂. Additional ground

water samples from the Tmss HSU will be collected and analyzed to establish the extent and magnitude of denitrification in this HSU. The water sample from one spring, Spring 11, which discharges from the toe of the Qls HSU landslide deposit, was the only other location sampled, that indicated significant isotopic enrichment. This isotopic enrichment may arise from surface processes and not ground water denitrification.

6.4.2.2. Contaminant Remediation and Mass Removal

The performance of and contaminant mass removal by the 854-SRC, 854-PRX, and 854-DIS ground water treatment systems during the five-year review period are discussed in Sections 6.4.2.2.1, 6.4.2.2.2, and 6.4.2.2.3, respectively. Time-series plots of cumulative total VOC and perchlorate mass removed by these facilities are shown on Figures 11 and 12, respectively.

6.4.2.2.1. 854-SRC GWTS

The 854-SRC GWTS began operation in December 1999, extracting and treating ground water to: (1) remove VOCs and perchlorate mass from the Building 854 source area, (2) minimize further plume migration from the source area, and (3) mitigate the TCE inhalation risk to onsite workers at Buildings 854A and F.

The facility originally utilized one extraction well, W-854-02, extracting at a flow rate of approximately 1 gpm. In September 2006, the extraction wellfield was expanded to include three additional extraction wells W-854-17, W-854-18A, and W-854-2218, extracting at an approximate combined flow rate of 3 to 4 gpm (Figure 20). However, after pumping from well W-854-17 for a period of time, it was determined that the yield from this well was extremely low and not sufficient to continue to operate as an extraction well. Therefore, extraction from well W-854-17 was discontinued, and the well is now used only for monitoring purposes.

Of the three current 854-SRC GWTS extraction wells, W-854-02 (operated constantly at 1 to 1.5 gpm) and W-854-2218 (operated constantly at 2 to 2.5 gpm) are relatively high pumping rate, high mass removal wells. Well W-854-18A sustainably extracts significantly less water (< 1gpm) and VOC mass.

The operation of the 854-SRC GWTS (and SVTS) has:

- Decreased VOC concentrations in the Building 854 source area from a pre-remediation maximum of 2,900 µg/L to 93 µg/L in the second semester of 2012.
- Removed over 5.7 kg of VOC, 0.16 kg of perchlorate, and 2,000 kg of nitrate from ground water.
- Mitigated unacceptable VOC inhalation risk to onsite workers at Building 854A.

VOC ground water mass removal is greatest the B854-SRC GWTS due relatively high concentrations, multiple extraction wells connected to the facility, and relatively high flow rates from one extraction well (W-854-02).

While good progress is being made in the remediation of the Building 854 source area, DOE/NNSA evaluated potential methods to optimize remediation in this area as part of this five-year review. The results of this evaluation are discussed below.

Extraction well W-854-02 currently and historically pumps at a constant flow rate of approximately 1 gpm with approximately 7 ft of available drawdown, but is capable of pumping at a higher sustainable flow rate. The pumping water level in this well typically averages at

approximately 147 ft bgs, but the screen bottom is at 154.2 ft bgs; therefore, there is still approximately 7 ft of available drawdown. Extraction well W-854-2218 is also capable of pumping at a much higher sustainable flow rate. This well currently and historically pumps at a constant flow rate of approximately 2 gpm with approximately 18 ft of available drawdown. The pumping water level in this well typically averages at approximately 147 ft bgs, but the screen bottom is at 165 ft bgs; therefore, there is still approximately 18 ft of available drawdown.

If wells W-854-02 and W-854-2218 can be pumped at a higher sustainable flow rate, the total volume of ground water treated and VOC mass removed at 854-SRC can be increased. However, increased pumping will add to the total volume of 854-SRC GWTS effluent to be discharged at the existing misting towers, which are at or near capacity. Therefore, DOE/NNSA recommends (Section 9, Recommendation #1):

- Performing a pumping test at well W-854-2218 to determine the range of enhanced pumping rates and corresponding drawdown water levels.
- Increasing the pumping rates of extraction wells W-854-02 and W-854-2218 to maximize flow rates and further increase hydraulic capture.
- Evaluate the effluent discharge options at the 854-SRC GWTS since the effluent is currently discharged via misting towers, which are at or near capacity (i.e., additional misting towers, reinjection with *in situ* bioremediation).

Extraction well W-854-18A is not capable of pumping at a higher sustainable flow rate. This pump runs intermittently at 1 to 1.4 gpm and often dewateres the well. Well W-854-18A is currently pumping at maximum capacity and will continue to be pumped at the current rate, with no further modifications.

6.4.2.2.2. 854-PRX GWTS

The 854-PRX GWTS began operation in November 2000, extracting and treating ground water to: (1) remove VOCs, perchlorate, and nitrate, (2) capture the proximal and distal portions of the ground water plume emanating from the Building 854 source area, and (3) prevent further migration of ground water contaminants in the Tnbs₁/Tnsc₀ HSU.

Ground water is extracted from extraction well W-854-03 at an approximate flow rate of 1 gpm (Figure 21). VOC and perchlorate mass removed from ground water by the 854-PRX GWTS are presented on Figures 11 and 12, respectively.

The operation of the 854-PRX GWTS has:

- Decreased VOC concentrations in the Building 854 proximal area from a pre-remediation maximum of 270 µg/L to 15 µg/L in the second semester of 2012.
- Removed over 0.67 kg of VOCs, 0.16 kg of perchlorate, and 620 kg of nitrate from ground water.

VOC mass removal rates at this facility are lower than at the 854-SRC GWTS, primarily due to the lower concentrations and flow rates from this single extraction well facility. Perchlorate mass removal rates are similar to the 854-SRC facility, primarily due to perchlorate concentrations below reporting limits at two of three extraction wells in the source area.

While good progress is being made in the remediation of the Building 854 proximal area, DOE/NNSA evaluated potential methods to optimize remediation in this area as part of this five-year review. The results of this evaluation are discussed below.

Extraction well W-854-03 currently and historically pumps at a constant flow rate of approximately 1 gpm with approximately 16 ft of available drawdown, but is capable of pumping at a higher sustainable flow rate. However, the pumping rate is currently constrained by pump size/type, and the limited capacity of the nitrate biotreatment system and the infiltration trench.

As discussed in Section 5.3, while an evaluation of options for facility and discharge method modifications was conducted during the 2003-2008 five-year review period, evaluation progress was hampered by implementability constraints. These constraints include restrictions due to the presence of critical habitat for special status species in the area that limit effluent discharge options. Consultation with the U.S. Fish and Wildlife Service may be required prior to selecting and implementing an alternate discharge method. In addition, there may not be sufficient capacity in the effluent infiltration trench to accommodate significant increased flow from W-854-03, therefore other effluent discharge options were/will be evaluated. During the next five years, DOE/LLNL will continue to evaluate options for modifying the 854-PRX GWTS and effluent discharge method to accommodate increased flow from W-854-03 (Section 9, Recommendation #2). If the further analysis of the Tmss HSU discussed in Section 5.3 (#9) demonstrates a widespread assimilative capacity for nitrate reduction in this HSU, replacement of the biotreatment system by reinjection of nitrate-bearing effluent with *in situ* monitored natural attenuation of the nitrate may also be considered. A step-drawdown hydraulic test will also be conducted at well W-854-03 to determine sustainable pumping rates for this well, and the increase in the volume of extracted ground water to be treated and discharged. In addition, a capacity test will be conducted to determine the sustainable infiltration capacity of the trench in which treated facility effluent is currently discharged. After higher pumping rates from extraction well W-854-03 are implemented, hydraulic capture in the Tnbs₁/Tnsc₀ HSU will be re-evaluated. In order to better estimate hydraulic capture and assess ground water cleanup progress in this area, DOE/NNSA recommends installing at least one performance monitor well in the vicinity of 854-PRX extraction well W-854-03 (Section 9, Recommendation #3).

As discussed in Section 5.3 (#7), monitoring data for perchlorate in well W-854-1823, located approximately 300 ft southeast of the 854-PRX GWTS, indicate that perchlorate concentrations in this well continue to decrease towards cleanup standards both during the 2003 - 2008 five-year review period and historically. DOE/LLNL will continue to monitor perchlorate concentrations in this well. If monitoring over the next five years indicates that perchlorate concentrations in well W-854-1823 stabilize and remain above the 6 µg/L MCL cleanup standard or show increasing trends, DOE/LLNL will discuss implementing remedial measures in or near this well with the regulatory agencies (Section 9, Recommendation # 4).

6.4.2.2.3. 854-DIS

The 854-DIS GWTS began operation in July 2006 extracting and treating ground water to: (1) remove VOCs and perchlorate, (2) capture the contaminant plume in the vicinity of former Well 13, and (3) prevent further migration of ground water contaminants in the Tnbs₁/Tnsc₀ HSU (Figure 22).

Ground water is extracted cyclically from one well (W-854-2139) at a rate of approximately 1 gpm (Figure 21). The current operational flow rate averaged over time is approximately 700 to 800 gallons per month.

The operation of the 854-DIS GWTS has:

- Decreased VOC concentrations in the Building 854 distal area from a pre-remediation maximum of 59 µg/L to 32 µg/L in the second semester of 2012.
- Removed over 0.008 kg of VOC, 0.31 g of perchlorate, and 4.9 kg of nitrate from ground water.

Contaminant mass removal in the 854-DIS has been limited by low pumping rates. Lower VOC mass removal rates at this facility, as compared to the 854-SRC GWTS, are primarily due to the relatively lower flow rates from this single extraction well facility, and the comparatively low VOC concentrations in the 854-DIS extraction well.

While good progress is being made in the remediation of the Building 854 distal area, DOE/NNSA evaluated potential methods to optimize remediation in this area as part of this five-year review. The results of this evaluation are discussed below.

Ground water is extracted from well W-854-2139 at a low pumping rate because the formation around the well screen is rapidly dewatered and the well cannot sustain prolonged pumping at this rate. The current operational flow rate averaged over time is approximately 700 to 800 gallons per month. Extraction well W-854-2139 is currently pumping at maximum capacity. This facility should continue pumping at the current rate, with no further modifications.

As discussed in Section 5.3 (#6), monitoring data for perchlorate in well W-854-45, located approximately 1,000 ft south of the 854-DIS GWTS, indicate that while perchlorate concentrations in this well showed some fluctuations/slight increases during the 2003-2008 five-year review period, concentrations are generally stable at slightly above the cleanup standard. DOE/NNSA will continue to monitor perchlorate concentrations in this well. If monitoring over the next five years indicates that perchlorate concentrations in well W-854-45 stabilize and remain above the 6 µg/L MCL cleanup standard or show increasing trends, DOE/NNSA will discuss implementing remedial measures in or near this well with the regulatory agencies (Section 9, Recommendation # 4).

6.4.2.3. Capture Zone Analysis

Hydraulic capture of Building 854 OU ground water COCs by the 854-SRC, 854-PRX, and 854-DIS extraction wellfields was evaluated to determine the effectiveness of the extraction wells, and if adjustments to well operations (i.e., pumping rates) and/or wellfield expansions could improve remediation effectiveness. Capture zone analysis results are discussed by GWTS areas in Sections 6.4.2.3.1 through 6.4.2.3.3.

Figure 7 shows the hydraulic capture zones for the fully implemented ground water extraction and treatment remedy for the Building 854 OU. August 2012 data were used to prepare the ground water elevation contour map as this is the most recent month in which ground water elevations were measured while the five extraction wells were operating during the five-year review period. The capture zones depicted are conservative estimates of hydraulic capture and are based on August 2012 ground water equipotential contours. For cases where water elevation data are sparse, a Thiem solution for steady-state radial flow in the vicinity of a pumping well was used to control the ground water elevation contours. The capture zones depicted on Figure 7 are also depicted on Figures 15, 19 (2012 panel), 16, and 14 (2012 panel). Decreasing trends of VOC concentrations downgradient indicate the efficacy of treatment.

6.4.2.3.1. Capture Zone Analysis at 854-SRC GWTS

Contaminant mass removal from ground water in 854-SRC area is limited due to low extraction well yields. Figure 7 displays the zones of hydraulic capture and injection influence as estimated using the Thiem equation for steady-state radial flow to a well and pumping rates during August 2012. The capture zones are a conservative estimate of hydraulic capture and are representative of operations during the past five years.

As discussed in Section 6.4.2.2.1, while remediation at the Building 854 source area has been effective in reducing contaminant mass and concentrations and mitigating risk, DOE/NNSA recommends increasing pumping at extraction wells, W-854-02 and W-854-2218 to increase mass removal and hydraulic capture. After these higher pumping rates are implemented, hydraulic capture in the Tnbs₁/Tnsc₀ HSU will be re-evaluated.

6.4.2.3.2. Capture Zone Analysis at 854-PRX GWTS

Contaminant mass removal from ground water in 854-PRX area is limited due to low extraction well yield. Figure 7 displays the zone of hydraulic capture and injection influence as estimated using the Thiem equation for steady-state radial flow to a well and pumping rates during August 2012. The capture zone is a conservative estimate of hydraulic capture and is representative of operations during the past five years.

As discussed in Section 6.4.2.2.2, while remediation at the Building 854 proximal area has been effective in reducing contaminant mass and concentrations, DOE/NNSA recommends increasing pumping at extraction well W-854-03 to increase hydraulic capture (Section 9, Recommendation #3). After these higher pumping rates are implemented, hydraulic capture in the Tnbs₁/Tnsc₀ HSU will be re-evaluated. DOE/NNSA also recommended installing at least one performance monitor well in the vicinity of 854-PRX extraction well W-854-03 to better estimate hydraulic capture in the Tnbs₁/Tnsc₀ HSU (Section 9, Recommendation #4).

6.4.2.3.3. Capture Zone Analysis at 854-DIS GWTS

Contaminant mass removal from ground water in 854-DIS area is limited due to low extraction well yield. Figure 7 displays the zone of hydraulic capture and injection influence as estimated using the Thiem equation for steady-state radial flow to a well and pumping rates during August 2012. The capture zone is a conservative estimate of hydraulic capture and is representative of operations during the past five years.

As discussed in Section 6.4.2.2.3, DOE/LLNL will continue to monitor perchlorate concentrations in well W-854-45 over the next five years, and discuss implementing remedial measures in or near this well with the regulatory agencies if concentrations stabilize and remain above the 6 µg/L MCL cleanup standard or show increasing trends (Section 9, Recommendation #4).

6.4.3. Risk Mitigation Remediation Progress

This section discusses the progress to date of mitigating the baseline human health and ecological risks.

As presented in the first Building 854 OU Five-Year Review (2008), all onsite worker health risks have been mitigated:

- Cancer risk of 1×10^{-5} for the inhalation of VOCs into outdoor air at Building 854F. The risk evaluations performed for the 2003 and 2004 Annual Compliance Monitoring Reports (Dibley et al., 2004 and 2005) indicated the risk was $<10^{-6}$.
- Cancer risk of 9×10^{-6} for the inhalation of VOCs that volatilize from the subsurface soil into the indoor air of Buildings 854F. Building 854F was demolished in 2005, removing the exposure pathway and risk.
- Cancer risk of 7×10^{-5} for inhalation, ingestion, and dermal contact with PCB contaminated surface soil from the former Building 855 lagoon. The excavation of contaminated soil in 2005 mitigated this risk (Holtzaple, 2005).
- Cancer risk of 1×10^{-6} for the inhalation of VOCs that volatilize from the subsurface soil into the indoor air of Buildings 854A. The risk evaluations performed for the 2005 and 2006 Annual Compliance Monitoring Reports (Dibley et al., 2006b and 2007c) indicated the risk was $<10^{-6}$.

On September 28, 2011, EPA released updated toxicity values and contaminant characteristics for TCE in the Integrated Risk Information System (IRIS) (EPA, 2011). Currently, only the assessment of risk for the vapor inhalation pathway is expected to be significantly impacted by this change.

Between 2003 and 2005, inhalation risk and hazard resulting from transport of VOC vapors from ground water to the building foundations and subsequently into indoor ambient air was estimated using the Johnson-Ettinger Model (U.S. EPA, 2002). Between 2005 and 2011, the model results were updated to reflect the chemical-specific toxicity criteria referenced in the “Interim Final Guidance for the Evaluation and Mitigation of Subsurface Vapor Intrusion to Indoor Air” (DTSC, 2005). In 2011, U.S. EPA updated the toxicity values for a number of contaminants, including TCE. Also in 2011, the California Department of Toxic Substances updated the toxicity values for a number of contaminants. The current inhalation risk and hazard resulting from transport of VOC vapors from ground water to the building foundations and subsequently into indoor ambient air at Building 854A was estimated using the Johnson-Ettinger Model (U.S. EPA, 2002) after the cancer inhalation unit risk (IUR) and the non-cancer reference concentration (RfC) were updated based on the 2011 California Department of Toxic Substances criteria. For TCE, the IUR was 4.1×10^{-6} per $(\mu \text{g}/\text{m}^3)^{-1}$ and the RfC was 2.0×10^{-3} mg/m^3 .

In 2013, for this five-year review report, the risk assessment for the inhalation pathway to indoor air (Building 854A) was re-evaluated using the new TCE IUR of 4.1×10^{-6} $(\mu \text{g}/\text{m}^3)^{-1}$ and the new TCE RfC of 2.0×10^{-3} mg/m^3 . This evaluation was performed using the U.S. EPA Johnson-Ettinger Model (U.S. EPA, 2002) updated with the new TCE toxicity values. The evaluation results indicated an incremental cancer risk from vapor intrusion to indoor air was 9.9×10^{-7} . A risk assessment for outdoor and indoor air at Building 854F was not conducted using the new TCE toxicity criteria because this building was demolished in 2005. Active remediation using ground water and soil vapor extraction continues in the 854 source area.

No unacceptable hazards to ecological receptors were identified in the baseline ecological assessment. A Site-Wide Five-Year Ecological Review was performed in 2008 (Dibley et al., 2009b). No new ecological hazards were identified in the Building 854 OU. No information was identified during this review to question the ecological protectiveness of the remedy.

6.5. Interviews and Site Inspection

DOE/NNSA meets monthly with the EPA, RWQCB, and DTSC Remedial Project Managers (RPMs) and quarterly with a community action group at Technical Assistance Grant Meetings to discuss remediation activities, issues, and cleanup status and progress.

There is a continuous presence of Site 300 Environmental Restoration Program staff at Site 300 that routinely inspect the: (1) extraction wellfield and treatment facilities weekly, and (2) monitoring wellfield during sampling activities. The Site 300 Environmental Restoration Program conducts self-assessment inspections of facilities and DOE/NNSA conducts quarterly inspections of remediation activities at Site 300. The RWQCB RPM performs site inspections twice a year, and EPA and DTSC RPMs perform site inspections as requested. The EPA performed the construction completion inspection on February 5, 2008. The Five-Year Review Inspection was performed by DOE/NNSA on May 9, 2012. The Five-Year Review Inspection Checklist is included as Attachment B.

Operational issues and resulting corrective actions identified during routine inspections associated with the treatment systems and extraction wellfields are: (1) described in detail in the Site 300 Compliance Monitoring Reports that are issued semi-annually, and (2) discussed and presented in the RPM Project Updates that are issued prior to and discussed with the regulators at the monthly RPM meetings. The contents of the Project Updates are incorporated into the RPM meeting minutes that are distributed following the meetings.

7. Technical Assessment

The protectiveness of the interim remedy was assessed by determining if:

1. The interim remedy is functioning as intended at the time of the decision documents.
2. The assumptions used in the decision-making process are still valid.
3. Any additional information has been identified that would call the protectiveness of the interim remedy into question.

7.1. Remedy Function

The remedy was determined to be functioning as intended at the time of the decision documents because:

- Ground water and soil vapor extraction and treatment is reducing contaminant concentrations in the subsurface as discussed in Section 6.4.
- System operation procedures are consistent with requirements.
- Costs have generally been within budget, except when extra costs were incurred to address unanticipated problems or regulatory requests.
- Ground water extraction and treatment systems are performing as designed and will continue to be operated and optimized. Examples of types of optimization that may be considered include installing new extraction wells, adding higher capacity pumps to maximize yield and to increase hydraulic capture, and upgrading the treatment facilities to accommodate increased flow, where appropriate.

- No early indicators of potential interim remedy failure were identified.
- Institutional controls are in place. No current or planned changes in land use at the site suggest that they are not or would not be effective.

Overall, analytical data and capture zone modeling indicate that the primary objectives of the interim remedy in the Building 854 OU will be met including: (1) ongoing removal of contaminant mass from the Building 854 source area, (2) continued mitigation of the VOC inhalation risk to onsite workers at Buildings 854A and F, and (3) preventing further migration of ground water contaminants in the Tnbs₁/Tnsc₀ HSU. Continuing optimization efforts will improve the performance of the extraction wellfield, increase hydraulic capture, and continue removing contaminant mass.

7.2. Changes to Exposure Assumptions, Toxicity Data, Cleanup Levels, and Remedial Action Objectives

The assumptions used in the decision-making process was determined to still be valid because:

- There have been no changes in risk assessment methodologies or calculations that could call the protectiveness of the remedy into question.
 - There have been no changes in exposure pathways that could call the protectiveness of the remedy into question.
 - No new or previously unidentified unacceptable risk or hazard to human health or ecological receptors has been identified.
 - There have been no changes in land, building, or water use except that Building 854A was reactivated and is being periodically used as office type space.
 - No new contaminant sources have been identified.
 - No remedy byproducts have been identified.
- Changes in location-, chemical-, or action-specific ARARs or to-be-considered requirements:
 - The State of California established a Maximum Contaminant Level (MCL) (6 µg/L) for perchlorate on October 18, 2007. This action-specific ARAR and ARARs related to ground water cleanup were included in the 2008 Site-Wide ROD.
 - The EPA National Pollution Discharge Elimination System (NPDES) Pesticide Rule changed in 2011, however, no Site 300 treatment systems currently discharge to the ground surface or fall under an NPDES permit.
- Changes in toxicity and other contaminant characteristics:
 - On September 28, 2011, the U.S. EPA released updated toxicity values and contaminant characteristics for TCE in the IRIS. The updated cancer IUR for TCE is $4.0 \times 10^{-6} (\mu\text{g}/\text{m}^3)^{-1}$ and the non-cancer RfC for TCE is $2.0 \times 10^3 \text{ mg}/\text{m}^3$. Currently, the only significant impact of this change is presumed to be on the assessment of risk for the vapor inhalation pathway. As discussed in Section 6.4.3, the inhalation risks associated with TCE vapor intrusion from the subsurface into indoor and outdoor air for onsite workers at the Building 854 OU were evaluated using the new EPA toxicity

values for TCE. No unacceptable risk or hazard were identified for the vapor inhalation pathway. Therefore, the protectiveness of the remedy is not affected.

- In February 2012, the U.S. EPA released updated toxicity values and contaminant characteristics for PCE in the IRIS. However, PCE is not detected in Building 854 OU ground water, therefore the protectiveness of the remedy is not affected.
- The review found progress toward meeting the RAOs.

7.3. Other Information

No additional information was identified that would call the protectiveness of the remedy into question:

- The Health and Safety Plan and Site-Wide Contingency Plan are in place, sufficient to control risks, and properly implemented.
- No unanticipated events (i.e., natural disasters, new contaminants discovered) occurred that would call the protectiveness of the remedy into question.
- No additional information has been identified that would call the protectiveness of the interim remedy into question.
- No new technologies have been identified that are capable of accelerating or achieving cleanup in a more cost-effective manner.

8. Issues

No issues were identified during this evaluation.

9. Recommendations and Follow-Up Actions

While no issues were identified during the five-year process, and the selected remedy is performing as intended and demonstrating good progress in remediating ground water, DOE/NNSA recommends some follow-up actions to further expedite ground water cleanup:

1. Extraction wells W-854-02 and W-854-2218 for the 854-SRC GWTS are capable of pumping at higher sustainable flow rates. DOE/NNSA recommends:
 - Performing a pumping test at well W-854-2218 to determine the range of enhanced pumping rates and corresponding drawdown water levels.
 - Increasing the pumping rates of extraction wells W-854-02 and W-854-2218 to maximize flow rates and further increase hydraulic capture.
 - Evaluate the effluent discharge options at the 854-SRC GWTS since the effluent is currently discharged via misting towers, which are at or near capacity.
2. Continue the evaluation of options for modifying the 854-PRX GWTS and effluent discharge method to accommodate increased flow from extraction well W-854-03. This well is capable of pumping at a higher flow rate, however, the pumping rate is currently constrained by the limited capacity of the nitrate biotreatment system and the infiltration trench.

3. Install at least one performance monitor well in the vicinity of 854-PRX extraction well W-854-03 to better estimate hydraulic capture and assess ground water cleanup progress in this area.
4. Continue to monitor perchlorate in ground water in Tnbs₁/Tnsc₀ HSU monitor wells W-854-45 (near Building 858 approximately 1,000 ft south of 854-DIS) and W-854-1823 (approximately 300 ft southeast of 854-PRX). While perchlorate concentrations in these wells are slightly above the 6 µg/L MCL cleanup standard, concentrations trends are generally stable to decreasing. If monitoring over the next five years indicates that perchlorate concentrations in these wells stabilize and remain above the 6 µg/L MCL cleanup standard or show increasing trends, DOE/LLNL will discuss implementing remedial measures in or near these wells with the regulatory agencies.

No other follow-up actions were identified related to this Five-Year Review. The milestone dates are stated in the Summary Form.

10. Protectiveness Statement

The remedy at the Building 854 OU is currently protects human health and the environment in the short-term because there is no current exposure to site contamination. Exposure pathways that could result in unacceptable risk to onsite workers are being controlled by the implementation of institutional controls, the Health and Safety Plan, and the Contingency Plan. The remedy is protective in the long-term because institutional controls have been implemented to prevent potential future exposure to contaminated media, and the remedy will reduce Contaminant of Concern concentrations to meet cleanup standards.

The cleanup standards for Building 854 OU ground water are drinking water standards. Because drinking water standards do not differentiate between industrial and residential use, the ground water cleanup remedy will be protective under any land use scenario.

The cleanup standard for TCE in subsurface soil are to reduce concentrations to mitigate risk to onsite workers and prevent further impacts to ground water to the extent technically and economically feasible. Because some TCE may remain in subsurface soil following the achievement of these cleanup standards, a land use control prohibits the transfer of lands with unmitigated contamination that could cause potential harm under residential or unrestricted land use.

The land use control consists of implementing a land use covenant per Title 22 CCR, Division 4.5, Chapter 39, Section 67391, and deed restrictions per CERCLA 120(h) in the event that Site 300 property with unmitigated contamination that could cause potential harm under residential or unrestricted land use is transferred in the future. This land use control requirement is included in the Site-Wide ROD. This prohibition will remain in place until and unless a risk assessment is performed in accordance with current U.S. EPA risk assessment guidance and the DOE/NNSA, EPA, DTSC, and RWQCB agree that it adequately shows that no unacceptable risk for residential or unrestricted land use is present.

11. Next Review

The next statutory review will be conducted within five years of the signature date of this report (2018).

12. References

- Beller, H., V. Madrid, G. Hudson, W. McNab, and T. Carlsen (2004). *Biogeochemistry and Natural Attenuation of Nitrate in Groundwater at an Explosives Test Facility*. Applied Geochemistry 19, 1483 - 1494.
- Buscheck, M., J. Valett, M. Taffet, V. Dibley, V. Madrid, L. Ferry (2013), *First Five-Year Review Report for Operable Units 3 and 8 at Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (LLNL-AR-579495).
- California EPA. (2004), *Human-Exposure-Based Screening Numbers Developed to Aid Estimation of Cleanup Costs for Contaminated Soil*. Integrated Risk Assessment Section, Office of Environmental Health Hazard Assessment, California Environmental Protection Agency. November 2004, January 2005 Revision.
- Casciotti, K.L., D. Sigman, M. Hastings, J. Bohlke, and A. Hilkert (2002), *Measurement of the Oxygen Isotopic Composition of Nitrate in Seawater and Freshwater Using the Denitrifier Method*. Analytical Chemistry 74, 4905 - 4912.
- Carlsen, T., L. Paterson, T. Alfaro, and S. Gregory (2012), *Rare Plant Monitoring and Restoration at the Lawrence Livermore National Laboratory Experimental Test Site, Site 300, Project Progress Report 2007 through 2011*, Lawrence Livermore National Laboratory, Livermore, Calif. (LLNL-TR-585933).
- Daily, W., M. Denton, V. Dibley, P. Krauter, V. Madrid, S. Martins, J. Valett (2003), *Interim Remedial Design for the Building 854 Operable Unit at Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-153883).
- Dibley, V., R. Blake, T. Carlsen, M. Denton, R. Goodrich, S. Gregory, K. Grote, V. Madrid, C. Stoker, M. Taffet, J. Valett (2004), *2003 Annual Compliance Report for Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-206319).
- Dibley, V., T. Carlsen, S. Chamberlain, W. Daily, Z. Demir, M. Denton, R. Goodrich, S. Gregory, V. Madrid, M. Taffet, and J. Valett (2005), *2004 Annual Compliance Report for Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-206319-04).
- Dibley, V., J. Valett, L. Ferry (2006a), *Five-Year Review Report for the General Services Area Operable Unit at Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-220827).
- Dibley, V., T. Carlsen, S. Chamberlain, W. Daily, Z. Demir, M. Denton, R. Goodrich, S. Gregory, V. Madrid, D. Mason, P. McKereghan, M. Taffet, J. Valett (2006b), *2005 Annual Compliance Monitoring Report, Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-206319-05).
- Dibley, V., J. Valett, S. Gregory, and V. Madrid (2007a), *Five-Year Review Report for the Building 834 Operable Unit at Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-226628).

- Dibley, V., V. Madrid, and M. Denton (2007b), *Five-Year Review Report for the High Explosive Process Area Operable Unit at Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-232231).
- Dibley, V., T. Carlsen, S. Chamberlain, W. Daily, Z. Demir, M. Denton, R. Goodrich, S. Gregory, V. Madrid, D. Mason, P. McKereghan, M. Taffet, J. Valett (2007c), *2006 Annual Compliance Monitoring Report, Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-206319-06).
- Dibley, V., J. Valett, and M. Buscheck (2008a), *Five-Year Review Report for the Building 854 Operable Unit at Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-404822).
- Dibley, V., L. Ferry, M. Taffet, G. Carli, and E. Friedrich (2008b), *Engineering Evaluation/Cost Analysis for PCB-, Dioxin, and Furan-contaminated Soil at the Building 850 Firing Table, Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-233862).
- Dibley, V., L. Ferry, M. Taffet (2008c), *Action Memorandum for the Removal Action at the Building 850 Firing Table, Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (LLNL-AR-403206).
- Dibley, V., L. Ferry, S. Gregory, L. Hall, V. Madrid, L. Martello, E.N. Shiroma, M. Taffet, K.S. Wells (2009a), *Compliance Monitoring Plan/Contingency Plan for Environmental Restoration at Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (LLNL-AR-411239).
- Dibley, V., L. Ferry, M. Buscheck, Ed. (2009b), *2008 Annual Compliance Monitoring Report, Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-206319-08).
- Dibley, V., L. Ferry, M. Buscheck, Ed. (2009c), *First Semester 2009 Compliance Report for Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-206769-09).
- Dibley, V., L. Ferry, M. Buscheck, Ed. (2010a), *2009 Annual Compliance Monitoring Report, Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-206319-09).
- Dibley, V., L. Ferry, M. Buscheck, Ed. (2010b), *First Semester 2010 Compliance Report for Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-206769-10).
- Dibley, V., L. Ferry, M. Taffet, Z. Demir, V. Madrid, K. Moffitt, R. Ruiz, (2011a), *Remedial Action Completion Report for the Building 850/Pit 7 Complex Operable Unit Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (LLNL-AR-432791).
- Dibley, V., L. Ferry, M. Buscheck, Ed. (2011b), *2010 Annual Compliance Monitoring Report, Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-206319-10).
- Dibley, V., L. Ferry, M. Buscheck, Ed. (2011c), *First Semester 2011 Compliance Report for Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-206769-11).

- Dibley, V., L. Ferry, M. Buscheck, Ed. (2012a), *2011 Annual Compliance Monitoring Report, Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-206319-11).
- Dibley, V., L. Ferry, M. Buscheck, Ed. (2012b), *First Semester 2012 Compliance Report for Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-206769-12).
- Dibley, V., L. Ferry, M. Buscheck, Ed. (2013), *2012 Annual Compliance Monitoring Report, Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-206319-12).
- Dibley V., and L. Ferry (2012), *(Draft) Final Close Out Report for the Eastern General Services Area Subarea of Operable Unit 1 at Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (LLNL-AR-607015-DRAFT).
- DTSC (2005) *Interim Final Guidance for the Evaluation and Mitigation of Subsurface Vapor Intrusion to Indoor Air*. California Environmental Protection Agency – Department of Toxic Substances Control. December 15, 2005.
- DTSC (2011) *Final Guidance for the Evaluation and Mitigation of Subsurface Vapor Intrusion to Indoor Air (Vapor Intrusion Guidance)*. Department of Toxic Substances Control, California Environmental Protection Agency. October 2011. http://www.dtsc.ca.gov/AssessingRisk/upload/Final_VIG_Oct_2011.pdf
- Ferry L. and C. Holtzapple (2005), *Characterization Summary Report for the Building 812 Study Area at Lawrence Livermore National Laboratory Site 300*, U.S. Department of Energy and Lawrence Livermore National Laboratory, Livermore Calif., 21 pp. plus attachments.
- Ferry L. and C. Holtzapple (2006), *Characterization Summary Report for the Building 865 Study Area at Lawrence Livermore National Laboratory Site 300*, U.S. Department of Energy and Lawrence Livermore National Laboratory, Livermore Calif., 35 pp. plus attachments.
- Ferry, L., R. Ferry, W. Isherwood, R. Woodward, T. Carlsen, Z. Demir, R. Qadir, and M. Dresen (1999), *Final Site-Wide Feasibility Study for Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore Calif. (UCRL-AR-132609).
- Ferry, L., M. Dresen, Z. Demir, V. Dibley, V. Madrid, M. Taffet, S. Gregory, J. Valett, M. Denton (2006), *Final Site-Wide Remediation Evaluation Summary Report for Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-220391).
- Ferry, R., W. Daily, L. Ferry, G. Aarons, V. Madrid, J. Valett, Z. Demir (2001a), *Five-Year Review Report for the General Services Area Operable Unit at Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-14104).
- Ferry, R., M. Dresen, L. Ferry, W. Isherwood, and J. Ziagos (2001b), *Remedial Design Work Plan for Interim Remedies at Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-138470).
- Ferry, R., L. Ferry, S. Gregory, V. Madrid, J. Valett, (2002a), *Five-Year Review Report for the Building 834 Operable Unit at Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-144744).

- Ferry, R., L. Ferry, M. Dresen, and T. Carlsen (2002b), *Compliance Monitoring Plan/Contingency Plan for Interim Remedies at Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-147570).
- Ferry, L., and R. Kearns (2002), *Building 854 Operable Unit Characterization Summary Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif.
- Goodrich, R., and G. Lorega (Eds.) (2009), *LLNL Livermore Site and Site 300 Environmental Restoration Project Standard Operating Procedures (SOPs)*, Lawrence Livermore National Laboratory Livermore, Calif. (UCRL-MA-109115 Rev. 13).
- Helmig, A., V. Dibley, V. Madrid, and J. Valett (2011), *Five-Year Review Report for the Building 832 Canyon Operable Unit at Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-470073).
- Helmig, A., V. Dibley, V. Madrid, J. Valett, and L. Ferry (2012), *Second Five-Year Review Report for the High Explosive Process Area Operable Unit at Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (LLNL-AR-553611).
- Holtzapple, C. (2005), Excavation of polychlorinated biphenyl-contaminated soil at the Building 855 lagoon at Lawrence Livermore National Laboratory (LLNL) Site 300, Lawrence Livermore National Laboratory, Livermore, Calif. (letter report).
- Holtzapple, C. (2008), Construction Completion Report for the Pit 6 Landfill Operable Unit at Lawrence Livermore National Laboratory (LLNL) Site 300, Lawrence Livermore National Laboratory, Livermore, Calif. (letter report).
- Johnson, P.C., and R. A. Ettinger (1991), "Heuristic Model for Predicting the Intrusion Rate of Contaminant Vapors in Buildings," *Environ. Sci. Technol.* **25**, 1445–1452.
- Johnson, P.C. (2002), "Identification of Critical Parameters for the Johnson and Ettinger (1991) Vapor Intrusion Model," American Petroleum Institute *Bulletin No. 17*, Washington, D.C.
- Jury, W.A., Spencer, W.F., Farmer, W.J. (1983), *Behavior assessment models for trace organics in soil: I. Model description*. J. Environ. Qual. 12, 558-564. (Errata see: J. Environ. Qual. 16, 448).
- Kana, T., C. Darkangelo, M. Hunt, J. Oldham, G. Bennett, and J. Cornwell (1994), *Membrane Inlet Mass Spectrometer for Rapid High Precision Determination of N₂, O₂, and Ar in Environmental Water Samples*. Analytical Chemistry 66, 4166 - 4170.
- Kendall, C. (1998), *Tracing Nitrogen Sources and Cycling in Catchments*. Isotope Tracers in Catchment Hydrology. Elsevier, New York.
- LLNL (2004), *Operations and Maintenance Manual, Volume 1: Treatment Facility Quality Assurance and Documentation*, Lawrence Livermore National Laboratory, Livermore, Calif.
- LLNL (2008), *First Semester 2008 Compliance Report for Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-206769-08).
- Madrid, V., L. Ferry, A. Ritcey, J. Valett, and M. Verce (2002), *Interim Remedial Design for the High Explosives Process Area Operable Unit at Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-147095).

- Martins, S. (2007), *LLNL Environmental Restoration Division, Operations and Maintenance Manual, Volume XIII: Miniature Treatment Units (MTUs), Granular Activated-Carbon Units (GTUs), and Solar Treatment Units (STUs)*, Lawrence Livermore National Laboratory, Calif.
- Sigman, D., K. Casciotti, M. Andreani, C. Barford, M. Galanter, and J. Bohlke (2001), *A Bacterial Method for the Nitrogen Isotopic Analysis of Nitrate in Seawater and Freshwater*. Analytical Chemistry 73, 4145–4153.
- Singleton, M. J., Woods, K. N., Conrad, M. E., Depaolo, D. J., and Dresel, P. E., 2005. Tracking sources of unsaturated zone and groundwater nitrate contamination using nitrogen and oxygen stable isotopes at the Hanford Site, Washington. Environmental Science & Technology 39, 3563–3570.
- Stupfel, D.S. (1992), former LLNL TCE-brine system operator and Engineering Technical Associate, personal communication with J.R. Copland, Senior Hydrogeologist, SAIC.
- Taffet, M.J., L. Ferry, V. Madrid, T. Carlsen, Z. Demir, J. Valett, M. Dresen, W. Daily, S. Coleman, V. Dibley (2005), *Final Remedial Investigation/Feasibility Study for the Pit 7 Complex at Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-202492).
- U.S. DOE (1995), *Interim Record of Decision for the Building 834 Operable Unit Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-119791).
- U.S. DOE (1997), *Final Record of Decision for the General Services Area Operable Unit at Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-124061).
- U.S. DOE (2001), *Interim Site-Wide Record of Decision for Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-138470).
- U.S. DOE (2002), *Draft Department of Energy CERCLA Five-Year Review Guidance*, U.S. Department of Energy, Washington, D.C.
- U.S. DOE (2007), *Amendment to the Interim Site-Wide Record of Decision for the Pit 7 Complex at Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-222569).
- U.S. DOE (2008), *Site-Wide Record of Decision for Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-236665).
- U.S. EPA (2001), *Comprehensive Five-Year Review Guidance*, U.S. Environmental Protection Agency (EPA 540-R-01-007), OSWER Directive 9355.7-03B-P.
- U.S. EPA (2002), *OSWER Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance)*. EPA530-D-02-004.
- U.S. EPA (2010), *Institutional Controls: A Guide to Planning, Implementing, Maintaining, and Enforcing Institutional Controls at Contaminated Sites*, U.S. Environmental Protection Agency (EPA 540-R-09-001), OSWER Directive 9355.0-89.

- U.S. EPA (2011). Toxicological review of Trichloroethylene (CASRN 79-01-6) in support of summary information on the Integrated Risk Information System (IRIS). EPA/635/R-09/011F.
- U.S. EPA (2012). *Superfund Vapor Intrusion FAQs (Frequently Asked Questions)*. U.S. Environmental Protection Agency
http://www.epa.gov/superfund/sites/npl/Vapor_Intrusion_FAQs_Feb2012.pdf
- Valett, J., V. Dibley, V. Madrid, L. Ferry (2011), *Five-Year Review Report for the General Services Area Operable Unit at Lawrence Livermore National Laboratory, Livermore Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (LLNL-AR-486703).
- Valett, J., V. Dibley, V. Madrid, L. Ferry (2012), *Five-Year Review Report for the Building 834 Operable Unit at Lawrence Livermore National Laboratory, Livermore Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (LLNL-AR-499272).
- Webster-Scholten C.P., Ed. (1994), *Final Site-Wide Remedial Investigation for Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-MI-141567).
- Ziagos, J., and E. Reber-Cox (1998), *Building 854 Operable Unit Characterization Summary Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif.

13. Acronyms and Abbreviations

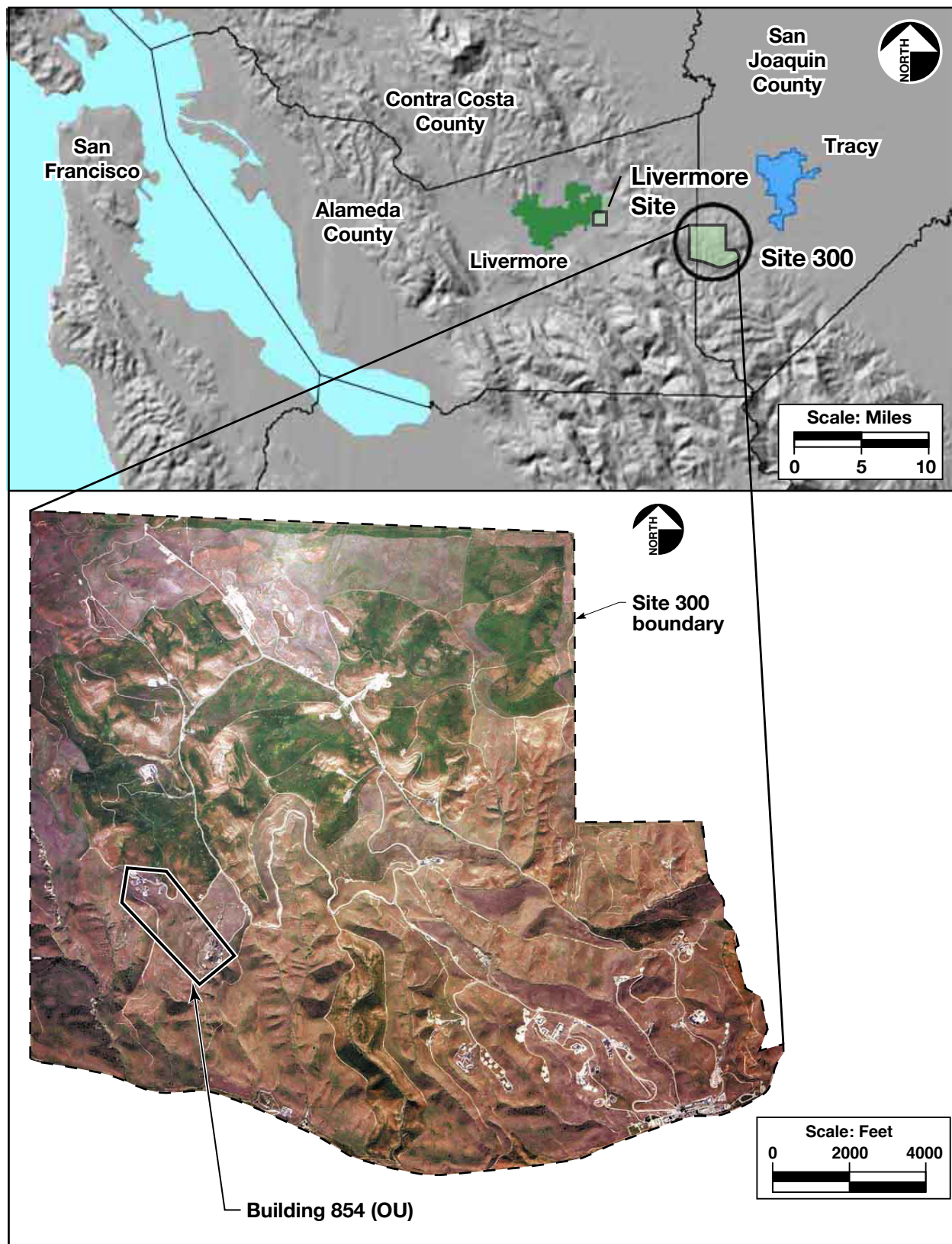
854-SRC	Building 854-Source
854-PRX	Building 854-Proximal
854-DIS	Building 854-Distal
ARARs	Applicable or relevant and appropriate requirements
ATA	Advanced Test Accelerator
bgs	Below ground surface
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CNPS	California Native Plant Society
COC	Contaminant of concern
DOE	Department of Energy
DTSC	Department of Toxic Substances Control
EPA	Environmental Protection Agency
ERD	Environmental Restoration Department
ESD	Explanation of Significant Difference
FFA	Federal Facility Agreement
ft	Feet
GAC	Granular activated carbon
gpm	Gallons per minute
GSA	General Services Area
GWTS	Ground water extraction and treatment system
HE	High explosives
HERD	Health and Environmental Risk Department
HMX	High-Melting Explosive
HSU	Hydrostratigraphic unit
IRIS	Integrated Risk Information System
IUR	Inhalation Unit Risk
kg	Kilogram
LLNL	Lawrence Livermore National Laboratory
LLNS	Lawrence Livermore National Security
MCL	Maximum contaminant level
mg/kg	Milligrams per kilograms
mg/L	Milligrams per liter
MNA	Monitored natural attenuation
N ₂	Nitrogen
NNSA	National Nuclear Security Administration
O&M	Operation and maintenance
OU	Operable unit
PCBs	Polychlorinated biphenyls

PCE	Tetrachloroethylene
pCi/L	PicoCuries per liter
PPCP	Pharmaceutical and Personal Care Product analytes
ppm _{v/v}	Parts per million on a volume per volume basis
Qls	Quaternary landslide deposits
RAOs	Remedial Action Objectives
RCRA	Resource Conservation and Recovery Act
RDX	Research Department explosive
RfC	Reference Concentration
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
RPMs	Remedial Project Managers
RWQCB	Regional Water Quality Control Board
SARA	Superfund Amendment Reauthorization Act
scfm	Standard cubic flow per minute
SVE	Soil vapor extraction
SVRA	State Vehicular Recreation Area
SVTS	Soil vapor extraction and treat system
TBOS/TKEBS	Tetrabutyl orthosilicate/Tetrakis (2-ethylbutyl) silane
TCE	Trichloroethylene
Tmss	Miocene Cierbo Formation—lower siltstone/claystone member
Tnbs ₁	Lower member of the Neroly lower blue sandstone
Tnsc ₀	Tertiary Neroly Formation—lower siltstone/claystone member
U.S.	United States
VOCs	Volatile organic compounds
yd ³	Cubic yards
µg/L	Micrograms per liter

Figures

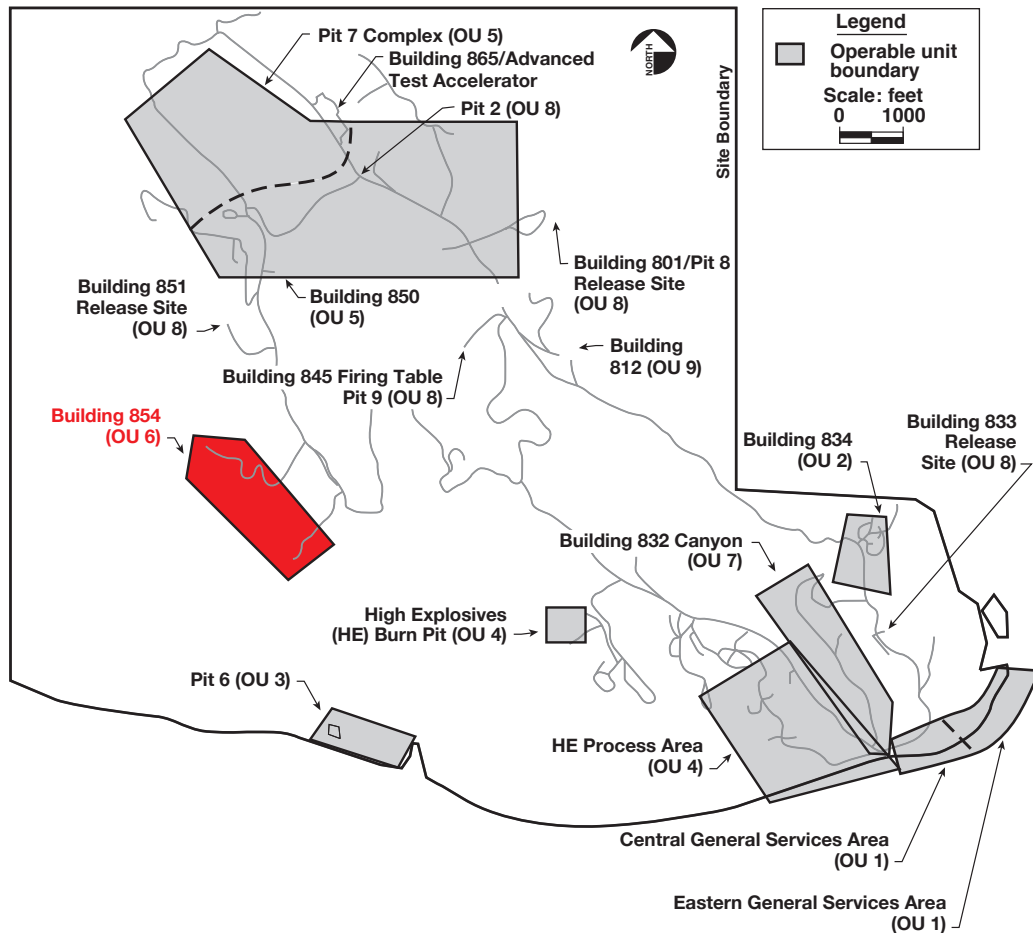
List of Figures

- Figure 1. Location of LLNL Site 300 and the Building 854 Operable Unit.
- Figure 2. Site 300 map showing Operable Unit locations.
- Figure 3. Site map showing monitor, extraction, injection and water-supply wells, and treatment facilities.
- Figure 4. Summary of stratigraphy and hydrostratigraphic units.
- Figure 5. Hydrogeologic cross-section A-A' showing total VOC concentrations.
- Figure 6. Hydrogeologic cross-section A-A' showing perchlorate concentrations.
- Figure 7. Ground water potentiometric surface map for the Tnbs₁/Tnsc₀ hydrostratigraphic unit, including hydraulic capture zones.
- Figure 8. Building 854 Operable Unit land use controls.
- Figure 9. Time-series plot of TCE in ground water in monitor well W-854-09.
- Figure 10. Building 854-Source soil vapor extraction system: operational history and historical trichloroethene (TCE) vapor concentrations in parts per million on a volume-to-volume basis (ppm_{v/v}).
- Figure 11. Time-series plots of cumulative mass of total VOCs removed by ground water extraction at each Building 854 treatment facility.
- Figure 12. Time-series plots of cumulative mass of perchlorate removed by ground water extraction at each Building 854 treatment facility.
- Figure 13. Comparison of the existing extraction wells and the distribution of total VOCs in ground water in the Tnbs₁/Tnsc₀ hydrostratigraphic unit in the second semester 2007 and the second semester 2012.
- Figure 14. Comparison of the existing extraction wells and the distribution of perchlorate in ground water in the Tnbs₁/Tnsc₀ hydrostratigraphic unit in the second semester 2007 and the second semester 2012.
- Figure 15. Map showing total VOC isoconcentration contours for the Tnbs₁/Tnsc₀ hydrostratigraphic unit.
- Figure 16. Map showing perchlorate isoconcentration contours for the Tnbs₁/Tnsc₀ hydrostratigraphic unit.
- Figure 17. Map showing nitrate concentrations for the Tnbs₁/Tnsc₀ hydrostratigraphic unit.
- Figure 18. Time-series plots of perchlorate in ground water in monitor wells W-854-45 and W-854-1823.
- Figure 19. Map showing ground water elevations, total VOCs, perchlorate, and nitrate concentrations for the combined Qls/Tnbs₁ hydrostratigraphic unit.
- Figure 20. Time-series plots of a) total VOCs, b) perchlorate and c) nitrate in ground water in the Building 854-Source area extraction wells and monthly facility flow.
- Figure 21. Time-series plots of a) total VOCs, b) perchlorate and c) nitrate in ground water in the Building 854-Proximal Area extraction wells and monthly facility flow.
- Figure 22. Time-series plots of a) total VOCs, b) perchlorate and c) nitrate in ground water in the Building 854-Distal Area extraction wells and monthly facility flow.



ERD-S3R-12-0101

Figure 1. Location of LLNL Site 300 and the Building 854 Operable Unit.

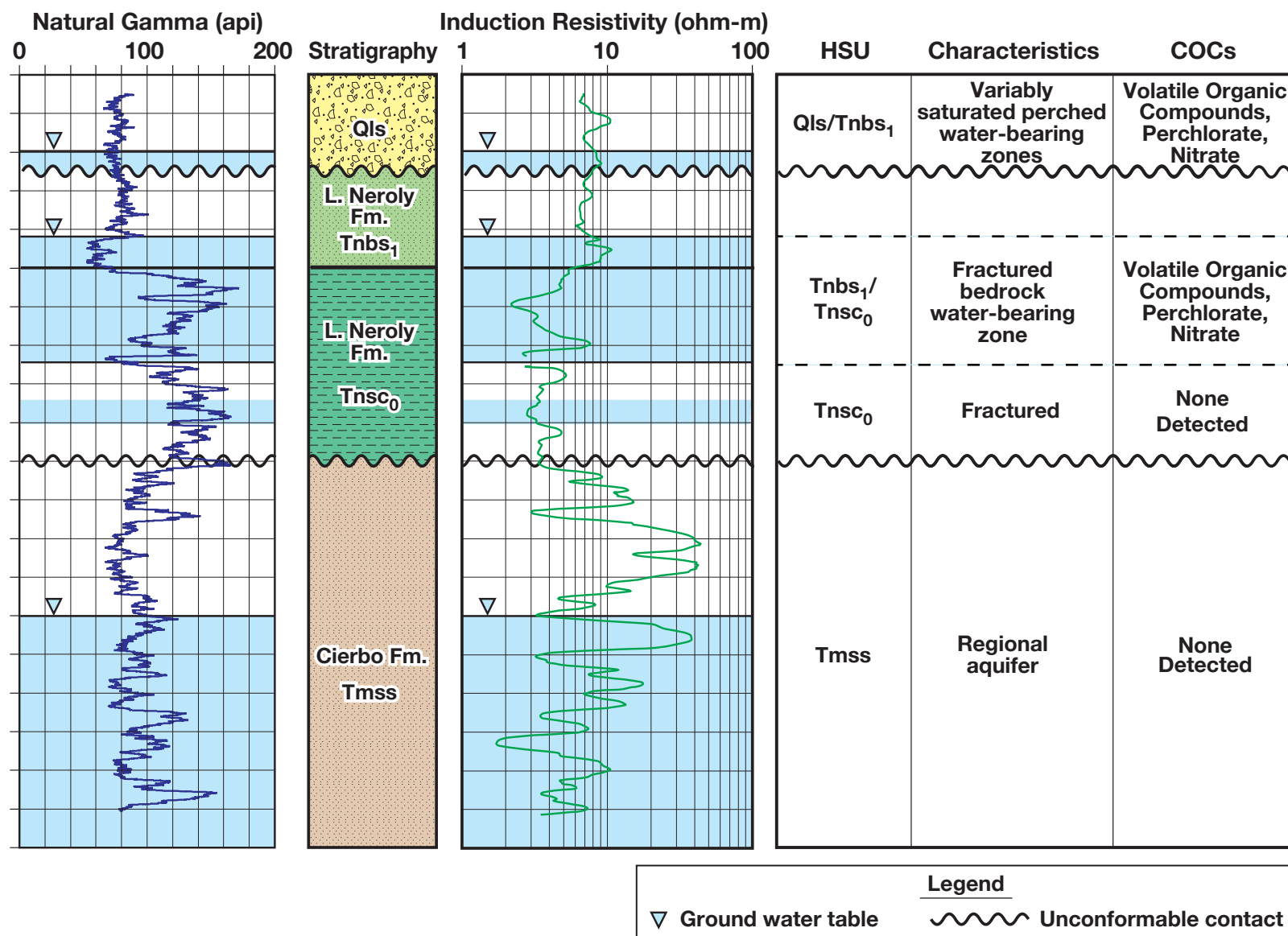


ERD-S3R-12-0102

Figure 2. Site 300 map showing Operable Unit locations.

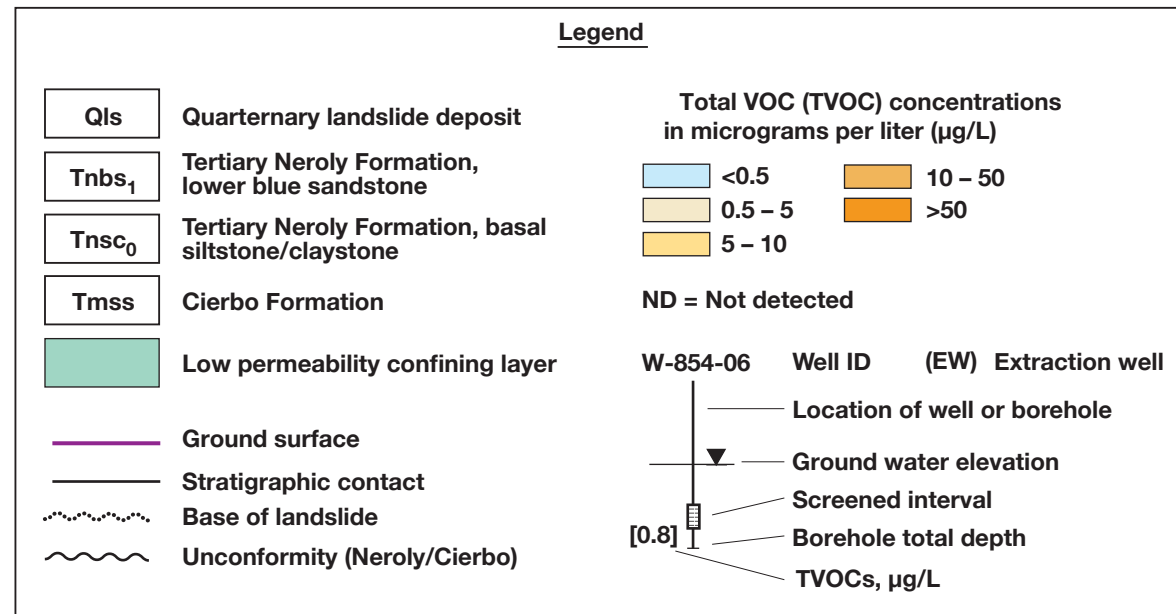
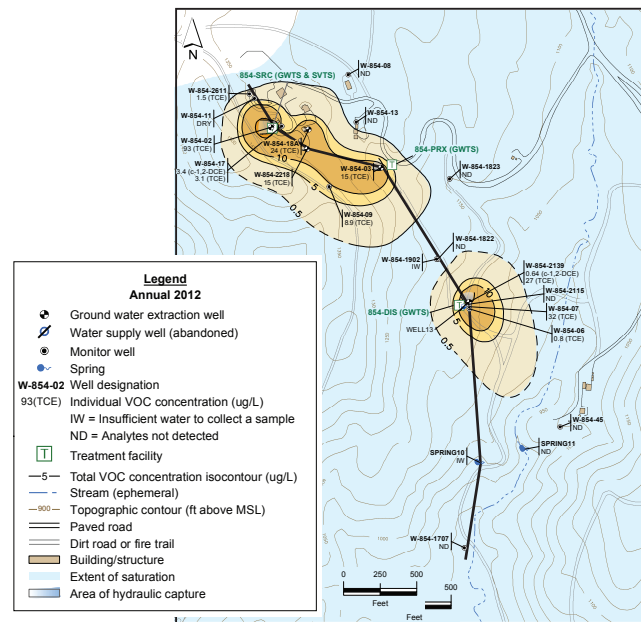
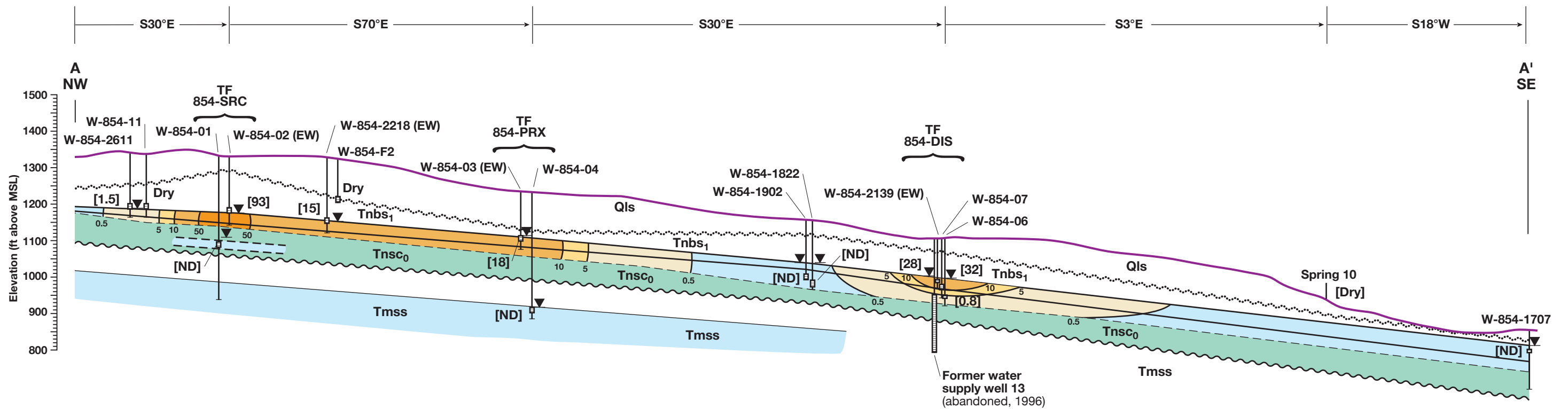


Figure 3. Site map showing monitor, extraction, injection and water-supply wells, and treatment facilities.



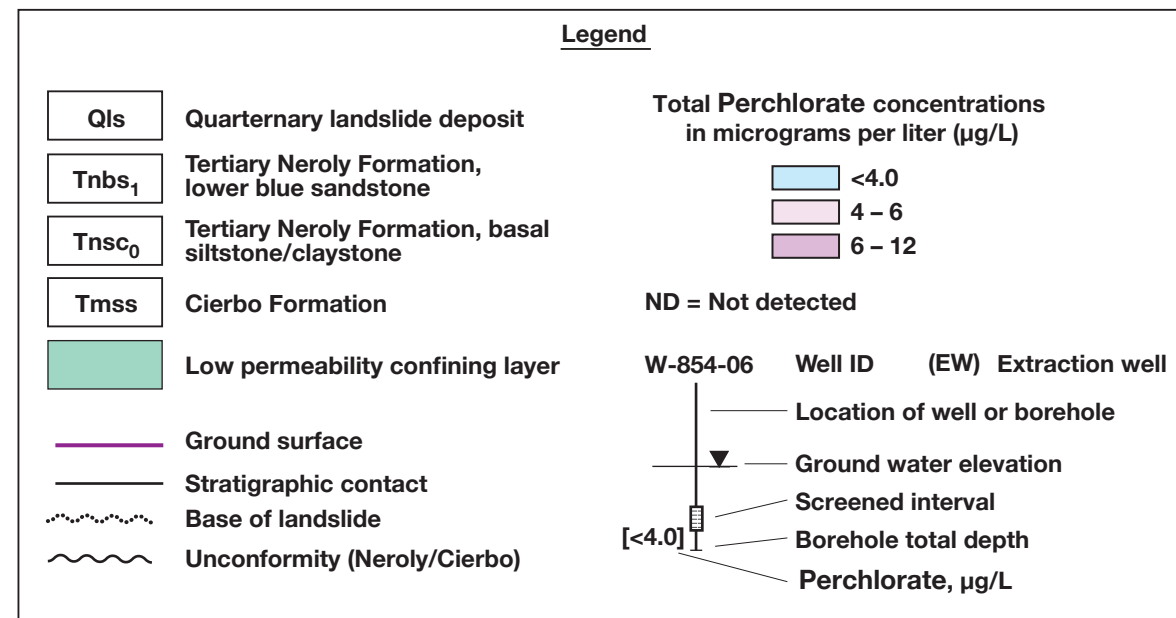
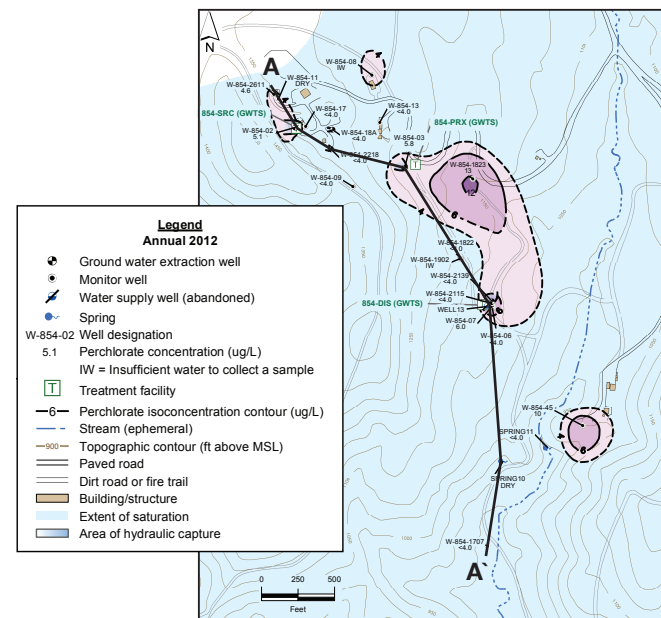
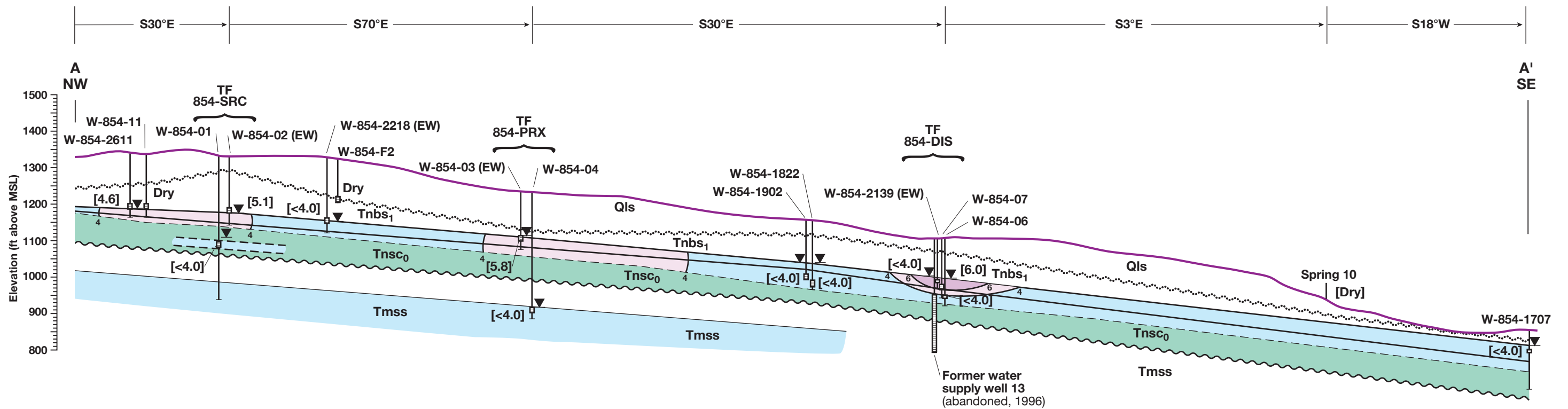
ERD-S3R-12-0103

Figure 4. Summary of stratigraphy and hydrostratigraphic units.



ERD-S3R-13-0050

Figure 5. Hydrogeologic cross-section A-A' showing total VOC concentrations.



ERD-S3R-13-0051

Figure 6. Hydrogeologic cross-section A-A' showing perchlorate concentrations.

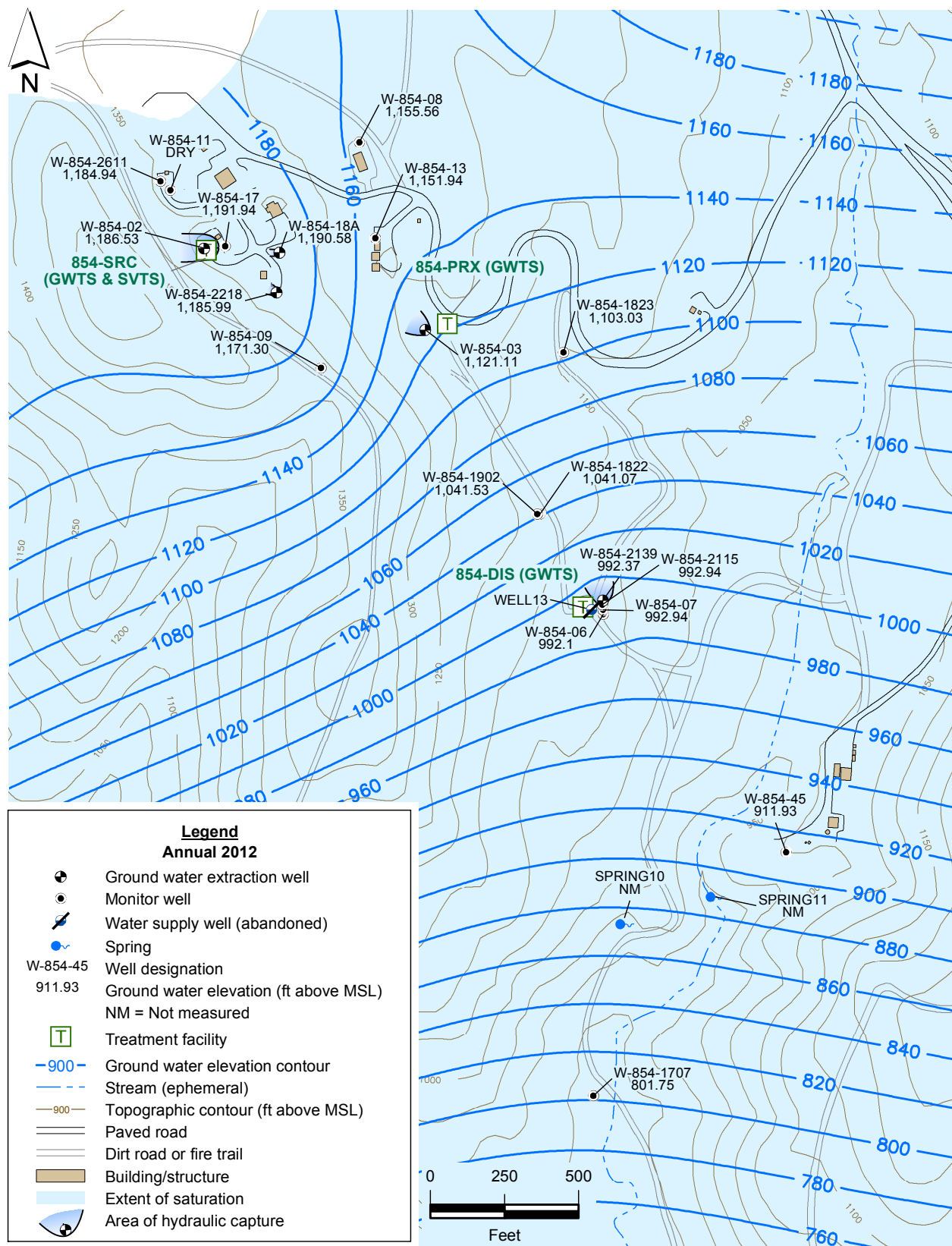
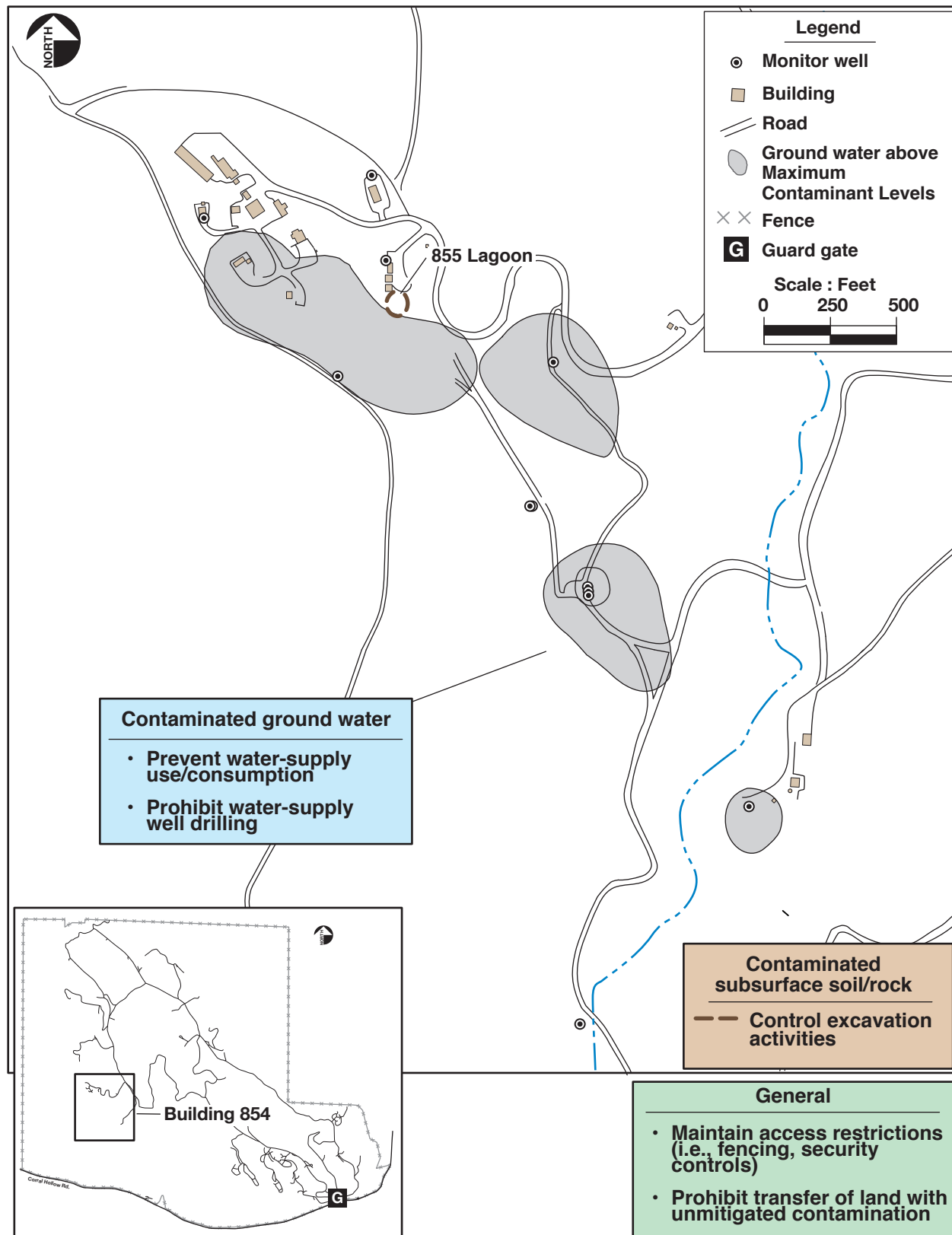
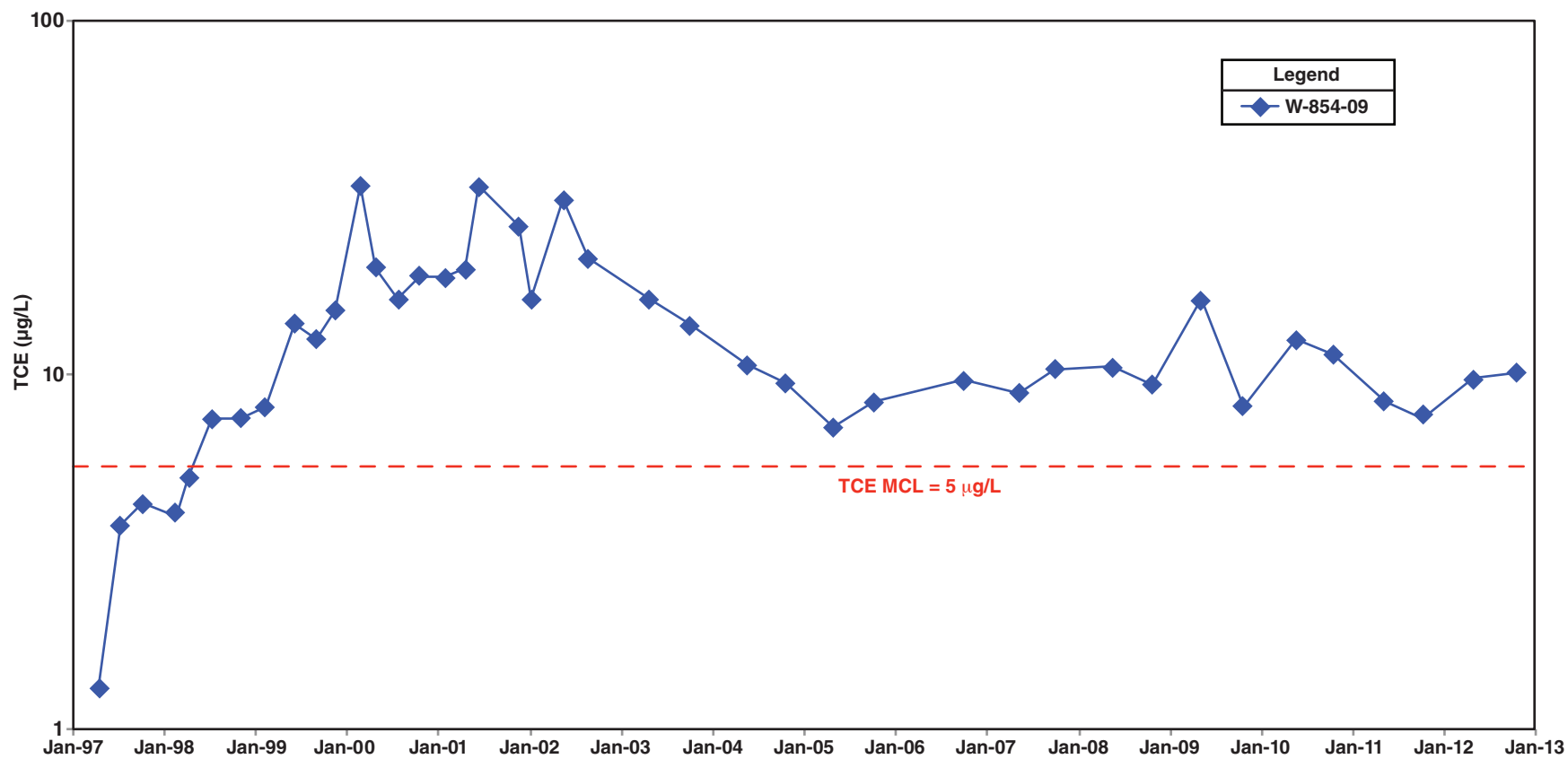


Figure 7. Ground water potentiometric surface map for the Tnbs₁/Tnsc₀ hydrostratigraphic unit, including hydraulic capture zones.



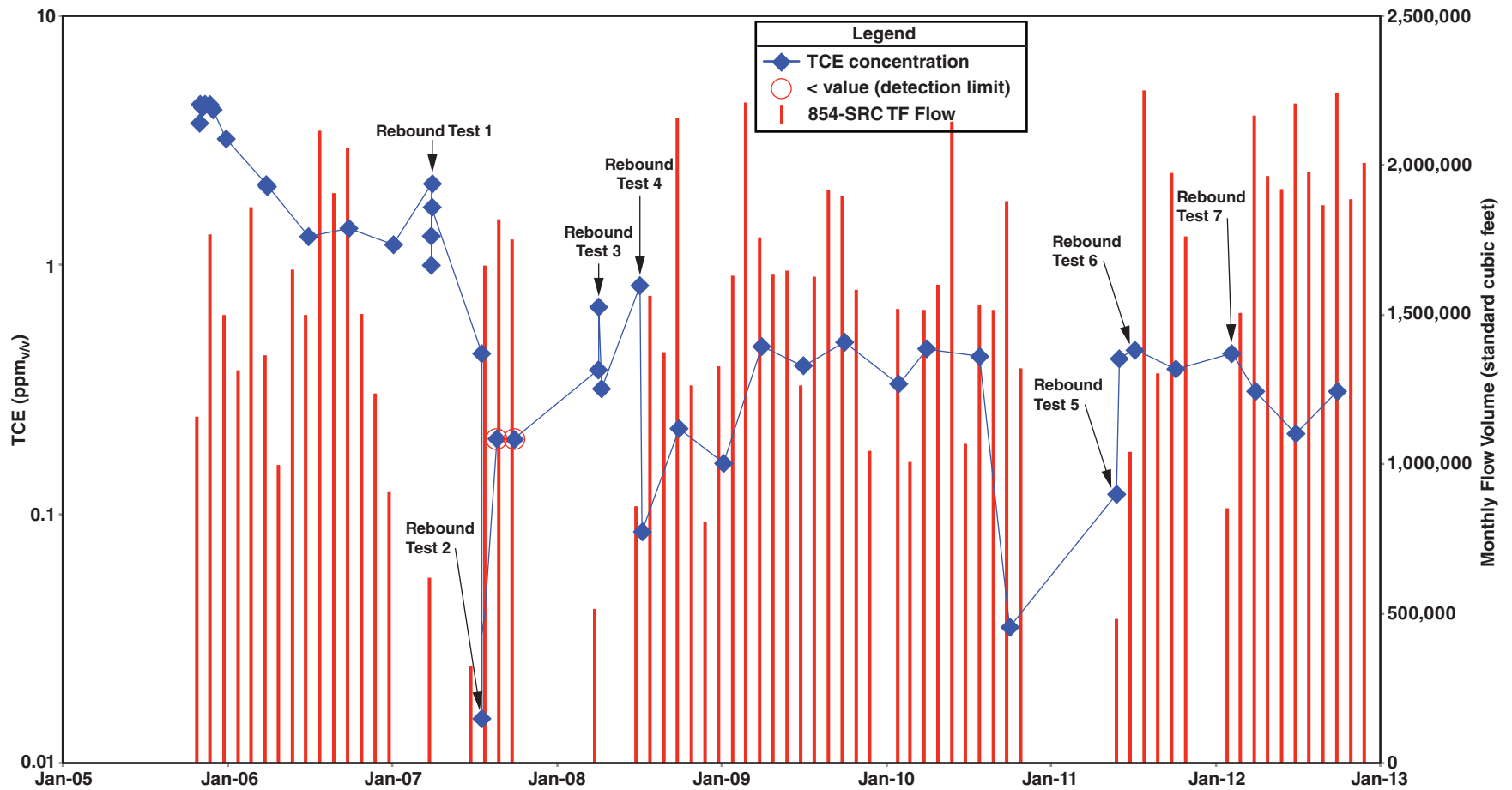
ERD-S3R-13-0044

Figure 8. Building 854 Operable Unit land use controls.



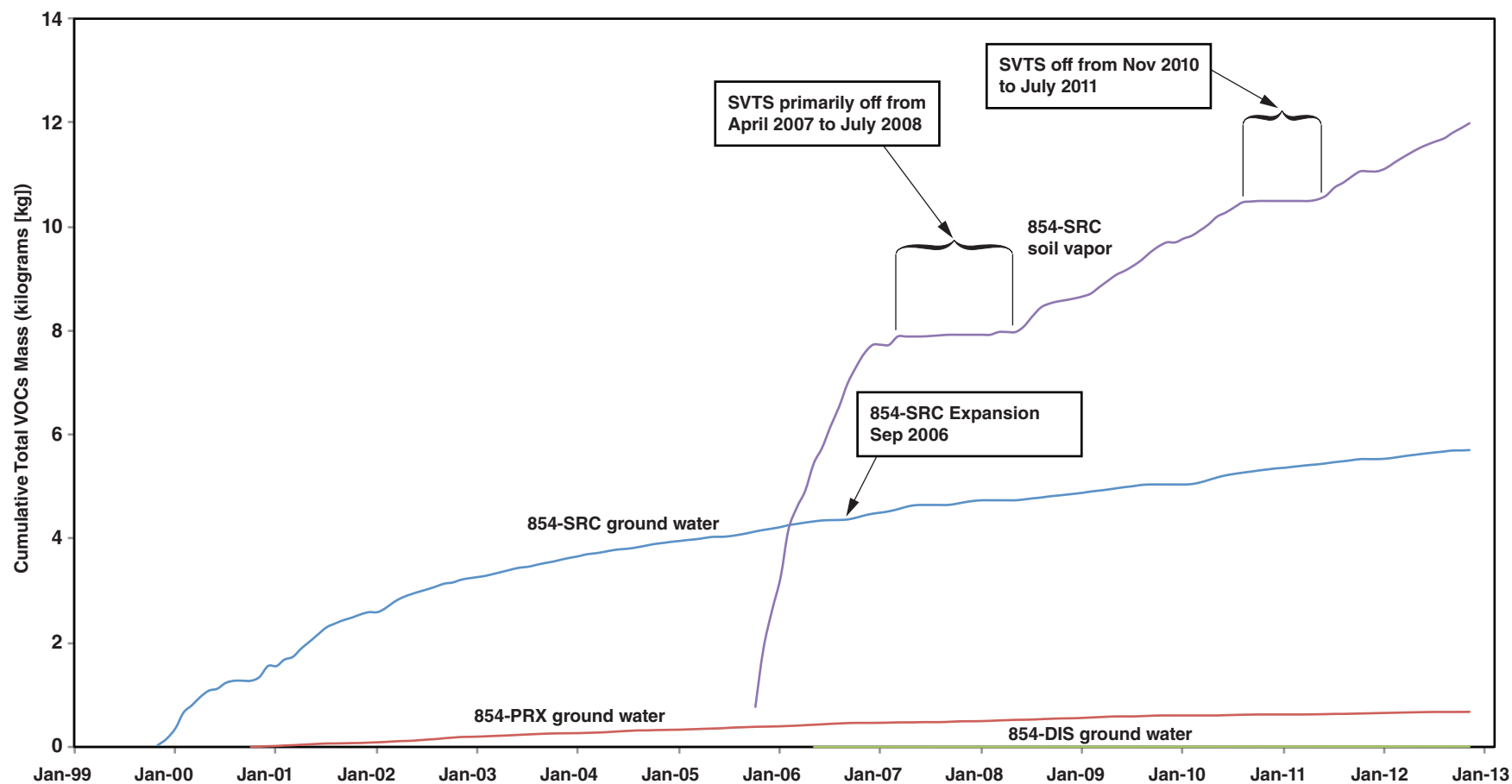
ERD-S3R-13-0048

Figure 9. Time-series plot of TCE in ground water in monitor well W-854-09.



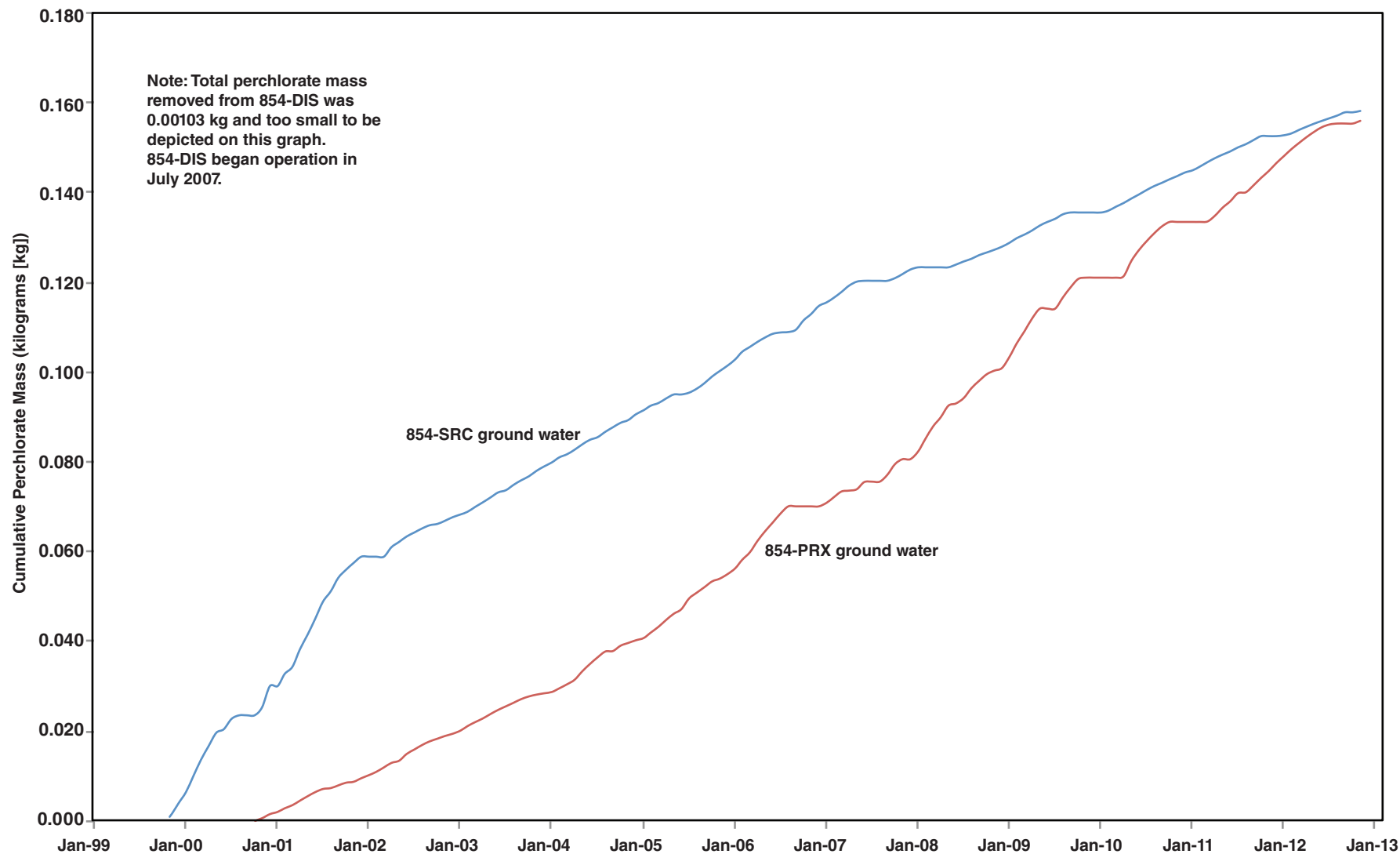
ERD-S3R-13-0042

Figure 10. Building 854-Source soil vapor extraction system: operational history and historical trichloroethene (TCE) vapor concentrations in parts per million on a volume-to-volume basis (ppm_{v/v}).



ERD-S3R-13-0052

Figure 11. Time-series plots of cumulative mass of total VOCs removed by ground water extraction at each Building 854 treatment facility.



ERD-S3R-13-0043

Figure 12. Time-series plots of cumulative mass of perchlorate removed by ground water extraction at each Building 854 treatment facility.

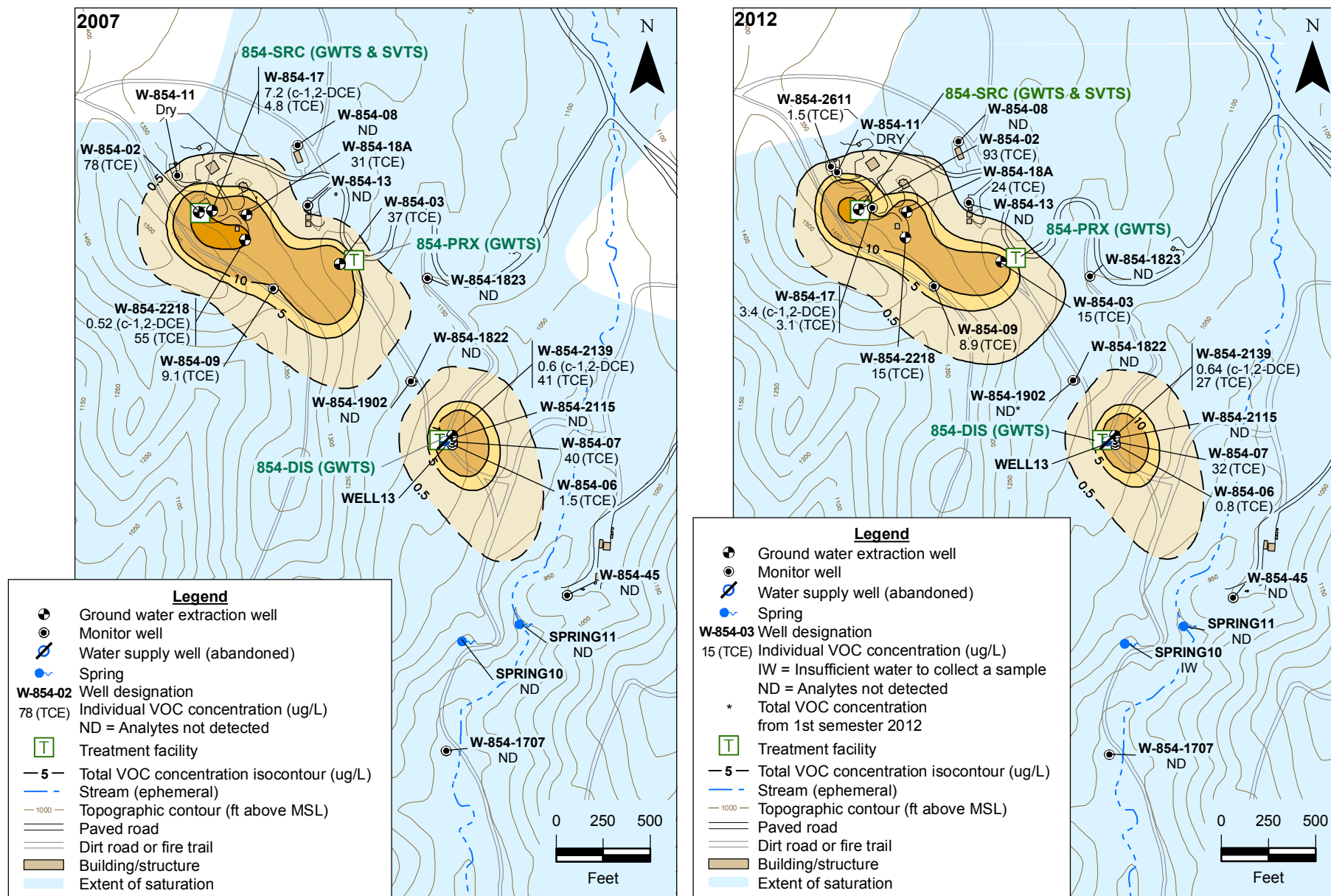


Figure 13. Comparison of the existing extraction wells and the distribution of total VOCs in ground water in the Tnbs₁/Tnsc₀ hydrostratigraphic unit in the second semester 2007 and the second semester 2012.

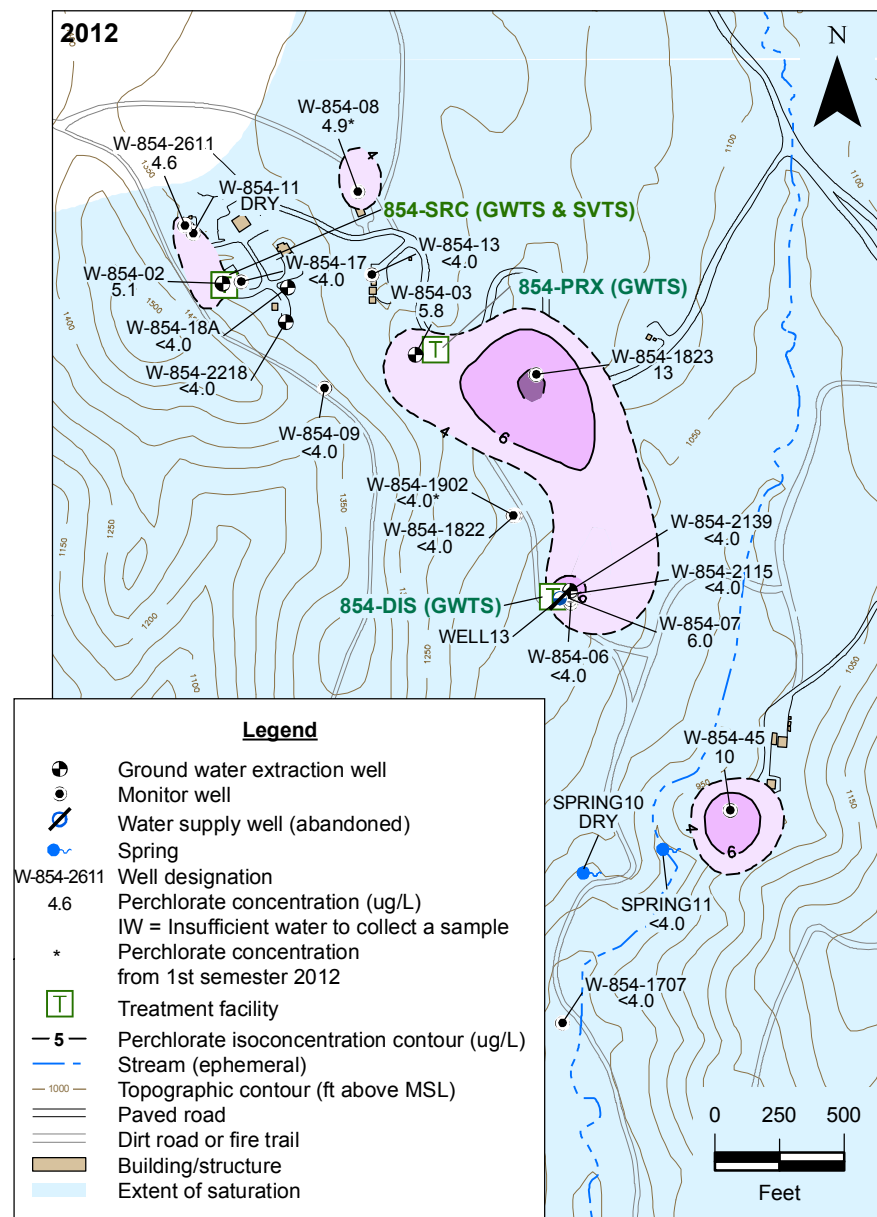
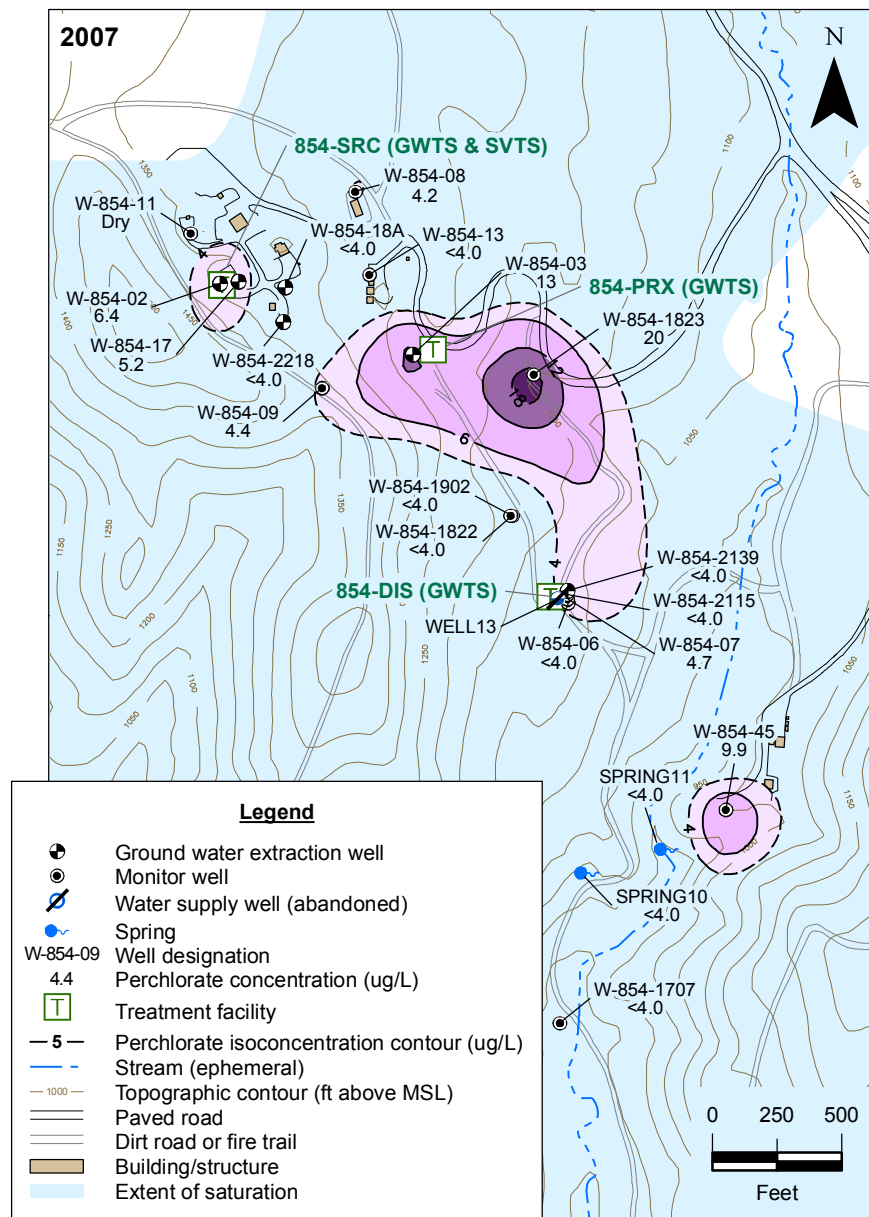


Figure 14. Comparison of the existing extraction wells and the distribution of perchlorate in ground water in the Tnbs₁/Tnsc₀ hydrostratigraphic unit in the second semester 2007 and the second semester 2012.

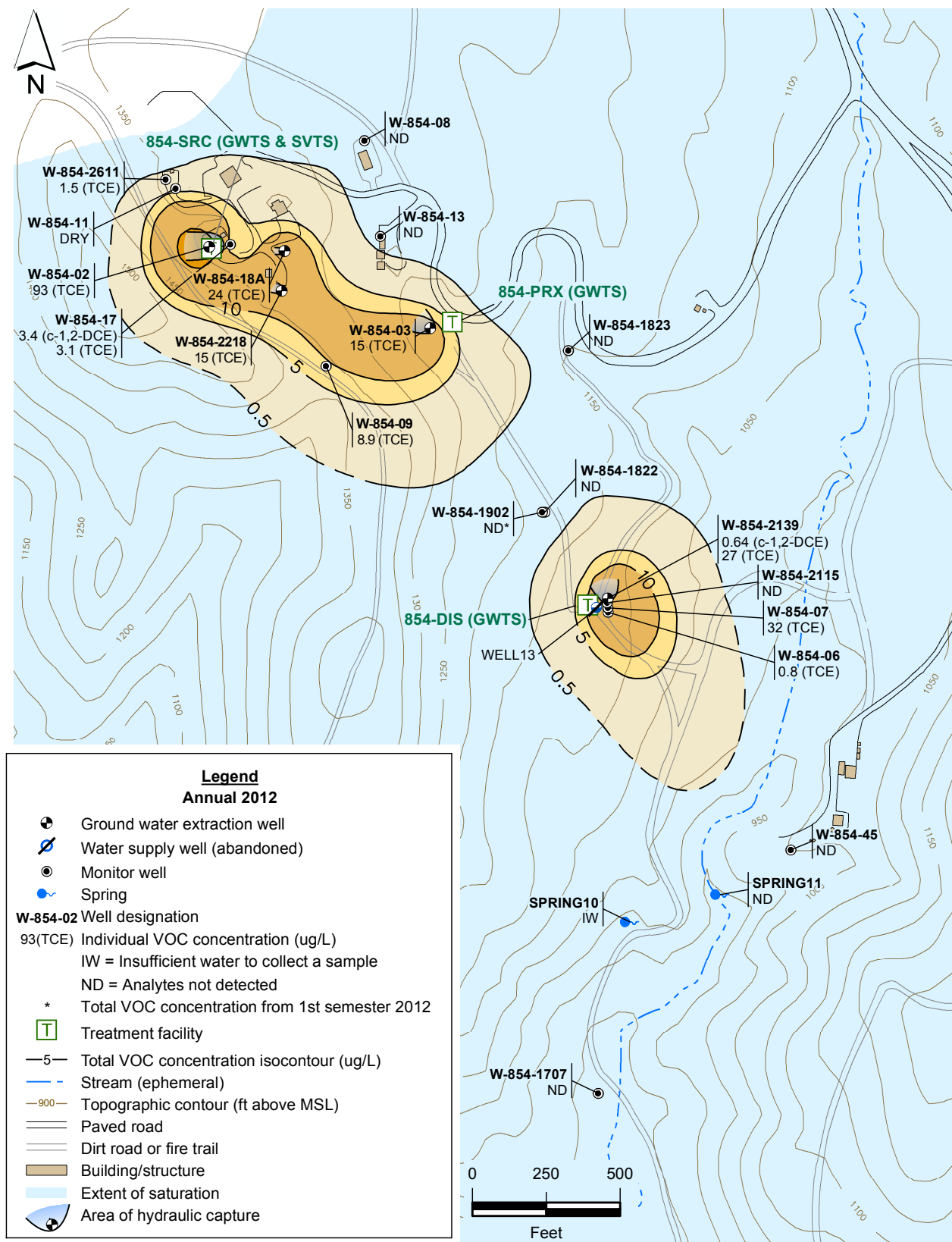


Figure 15. Map showing total VOC isoconcentration contours for the Tnbs₁/Tnsc₀ hydrostratigraphic unit.

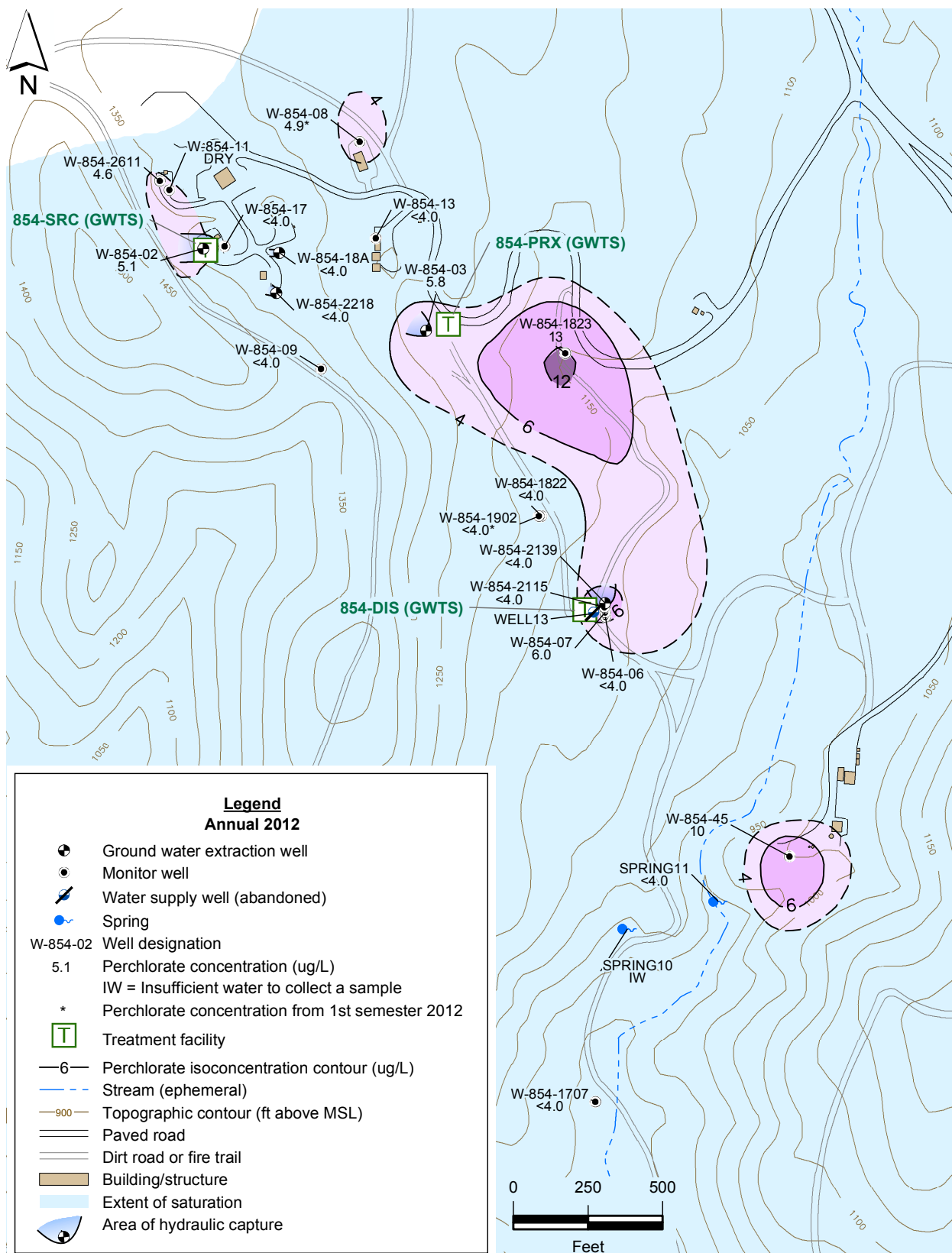


Figure 16. Map showing perchlorate isoconcentration contours for the Tnbs₁/Tnsc₀ hydrostratigraphic unit.

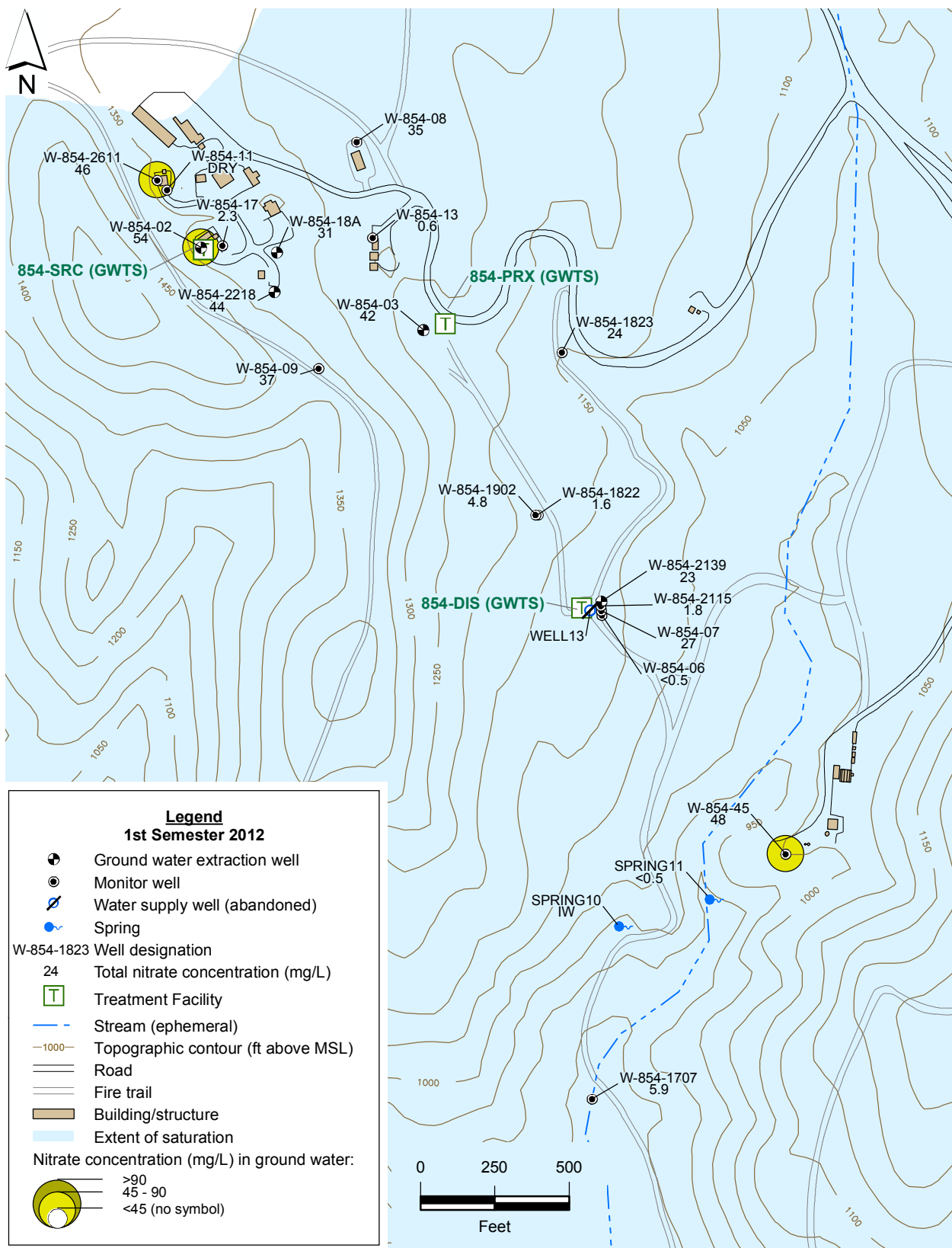
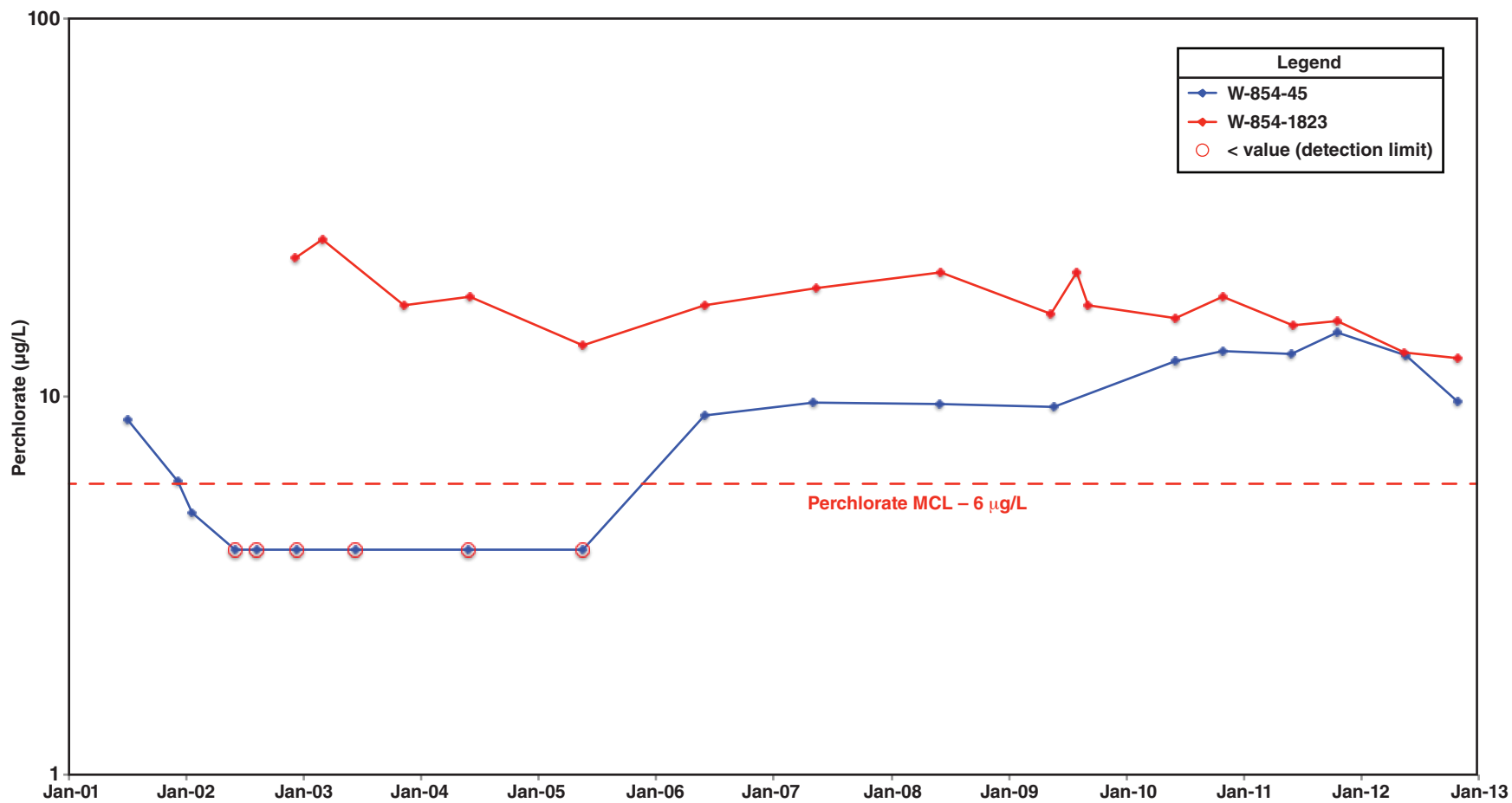


Figure 17. Map showing nitrate concentrations for the Tnbs₁/Tnsc₀ hydrostratigraphic unit.



ERD-S3R-13-0049

Figure 18. Time-series plots of perchlorate in ground water in monitor wells W-854-45 and W-854-1823.

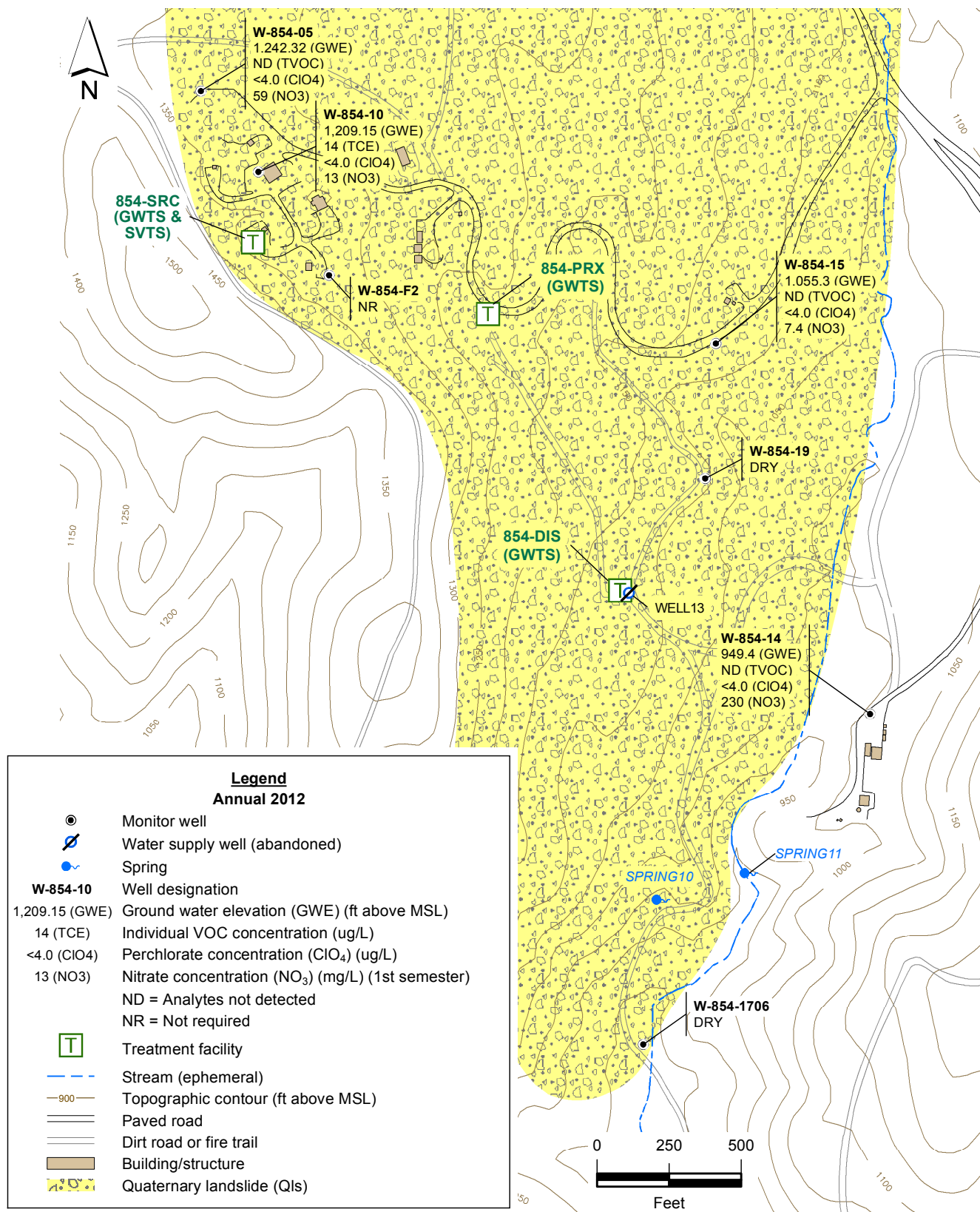
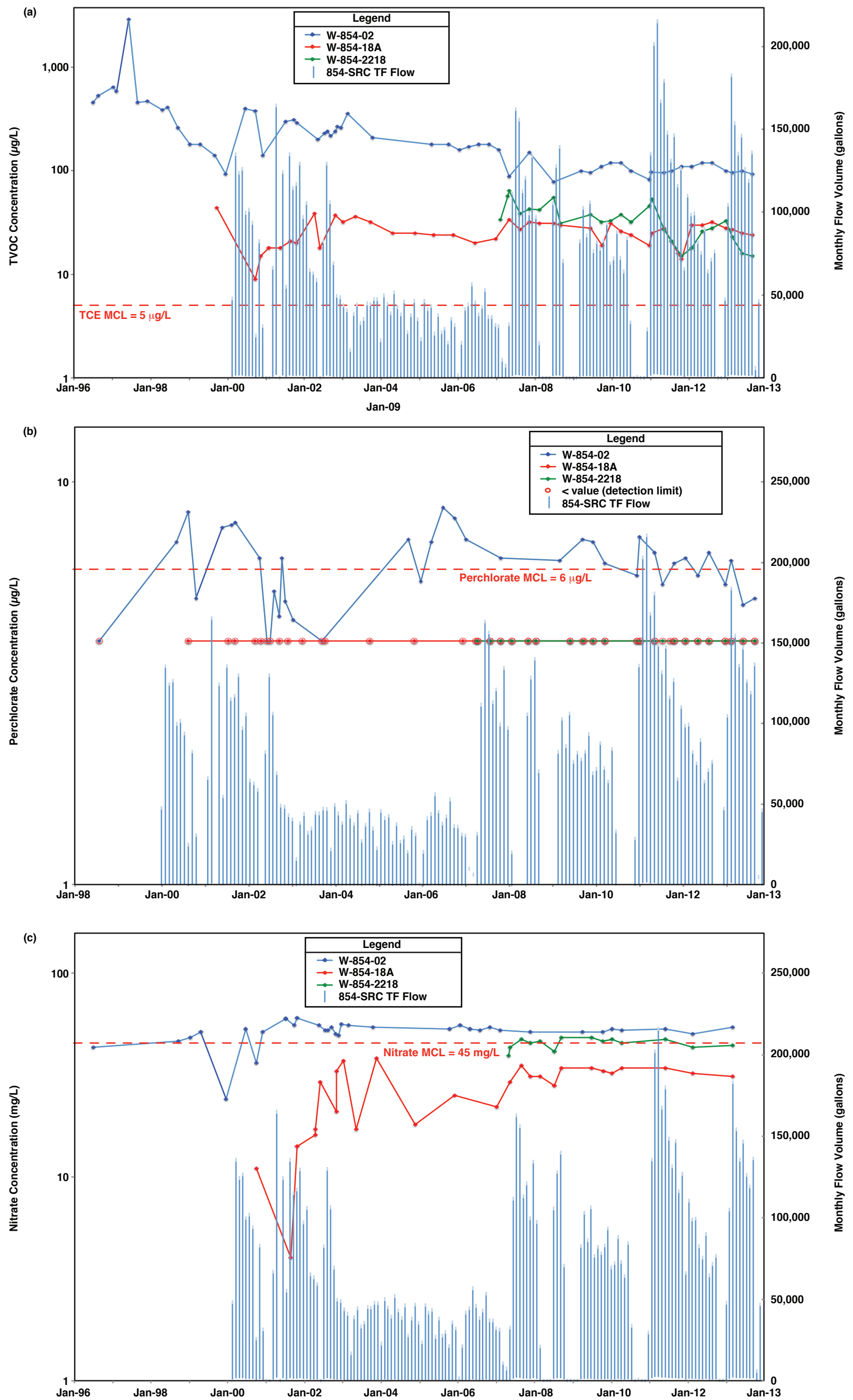
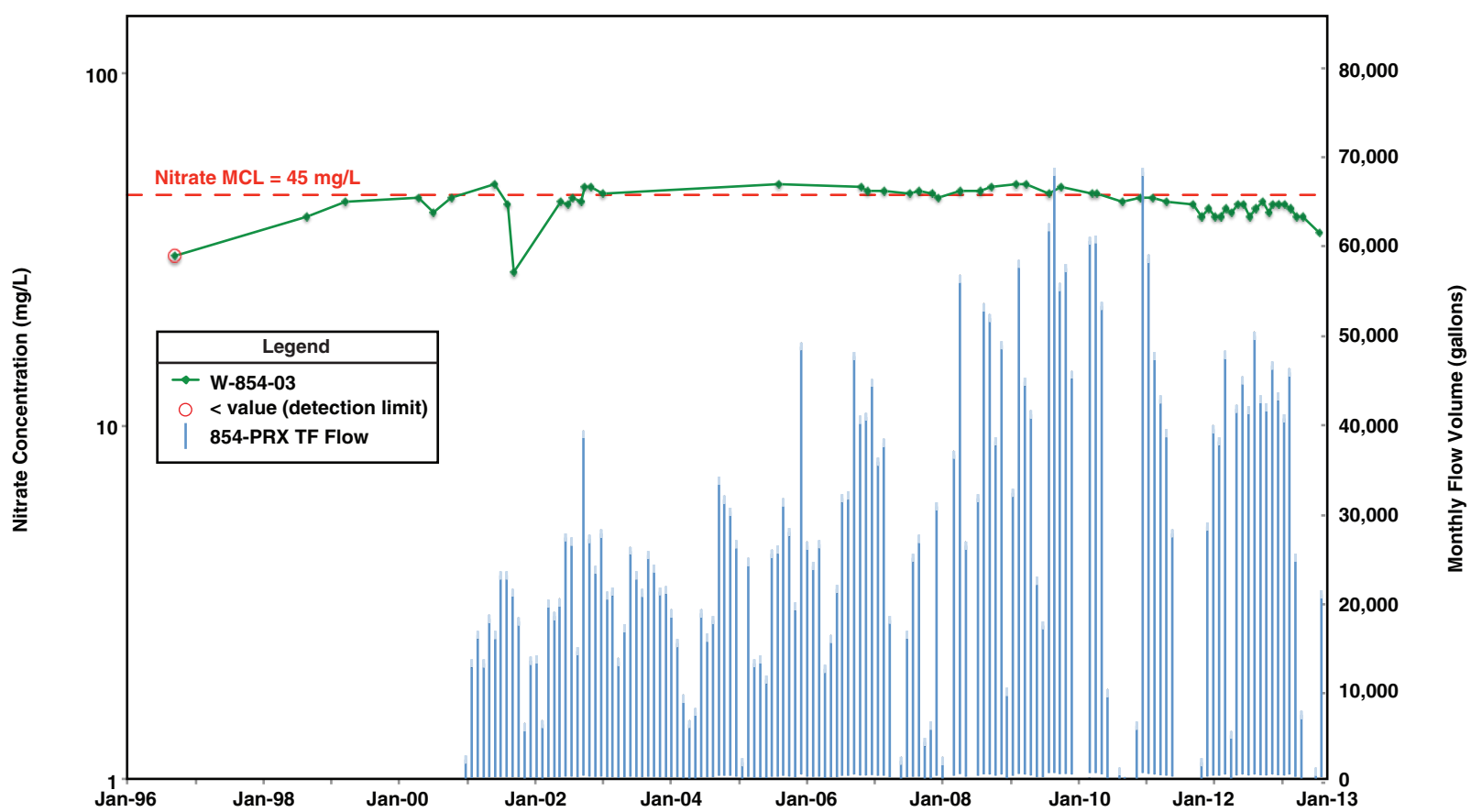
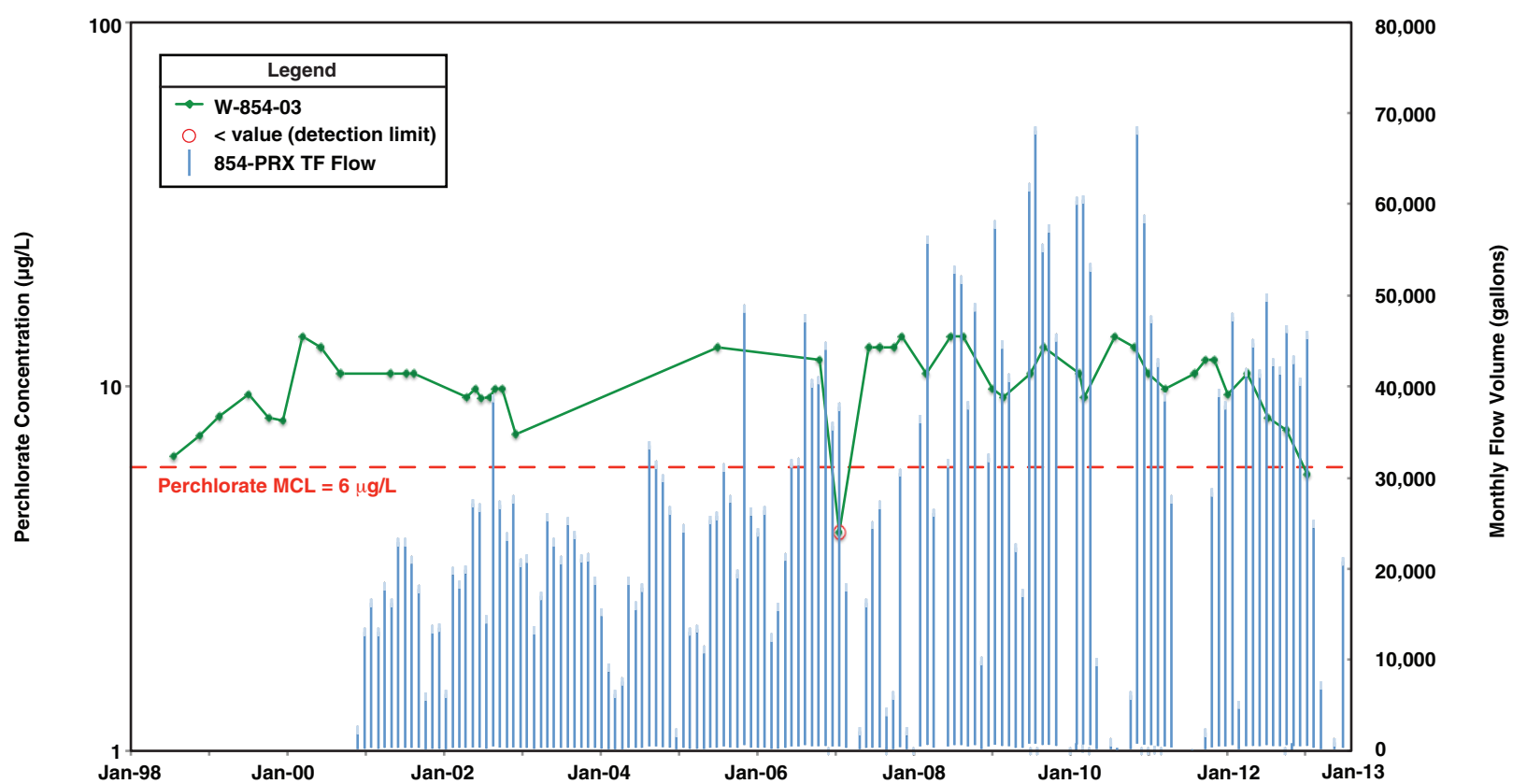
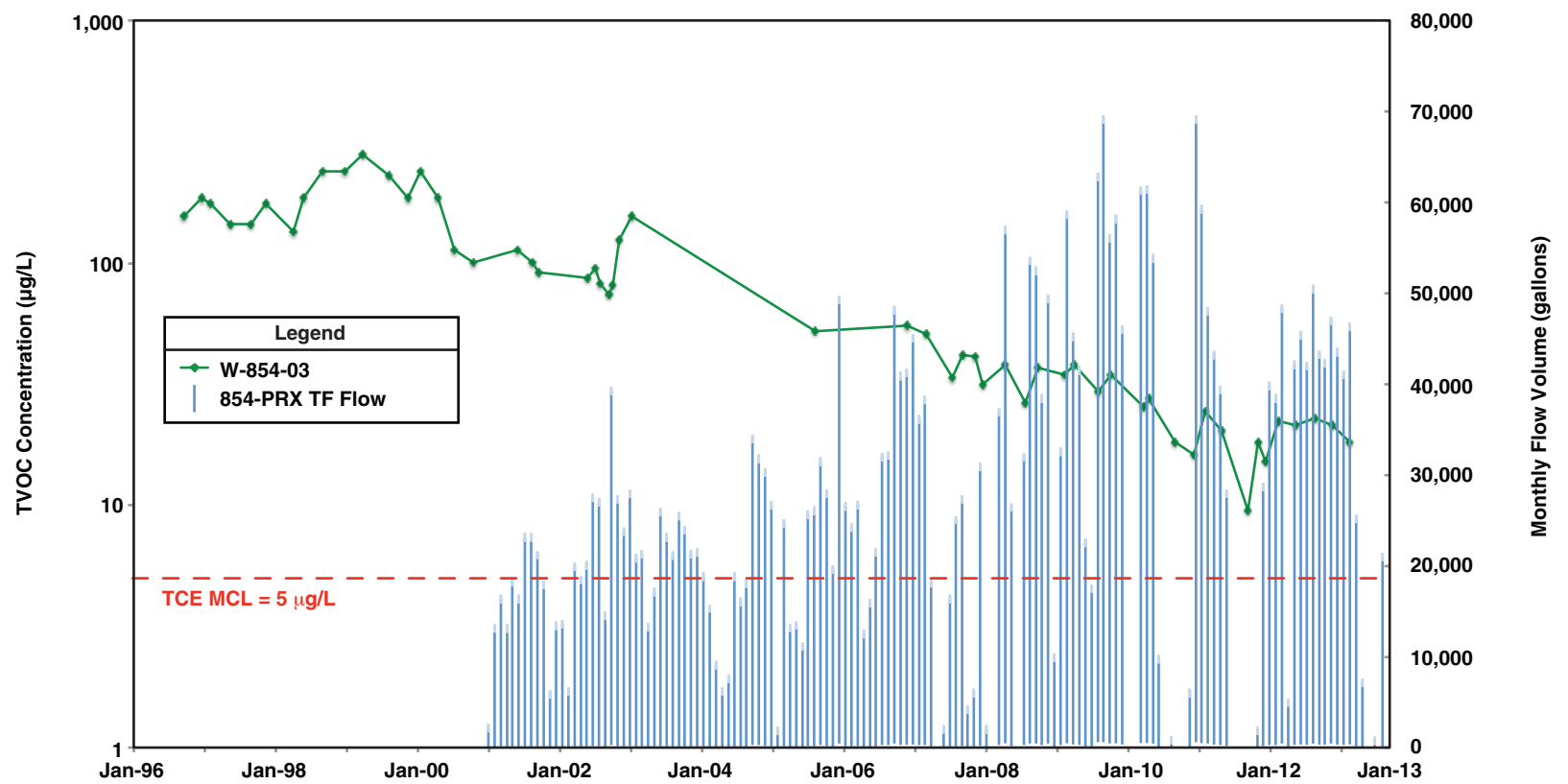


Figure 19. Map showing ground water elevations, total VOCs, perchlorate, and nitrate concentrations for the QIs/Tnbs₁ hydrostratigraphic unit.



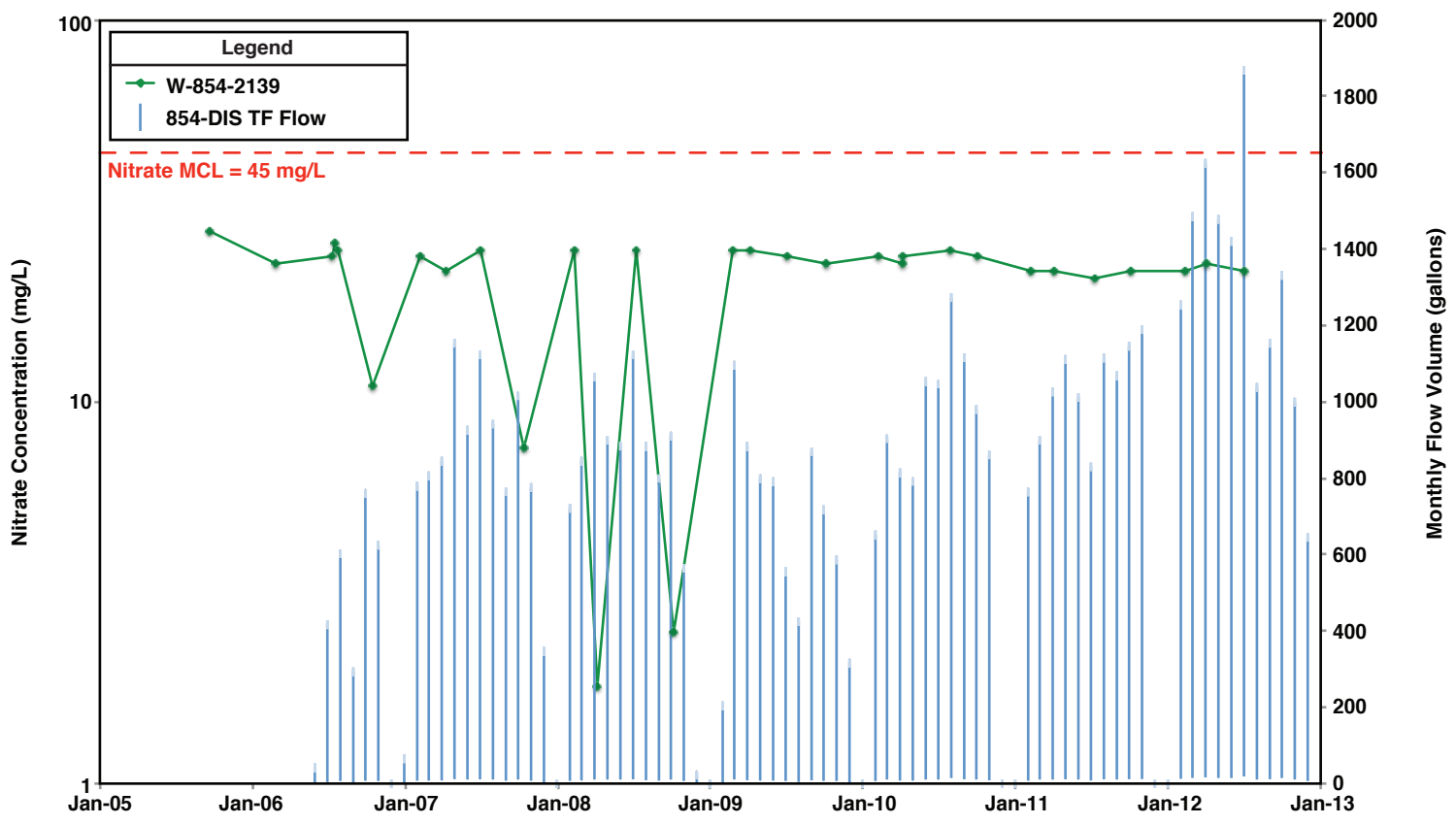
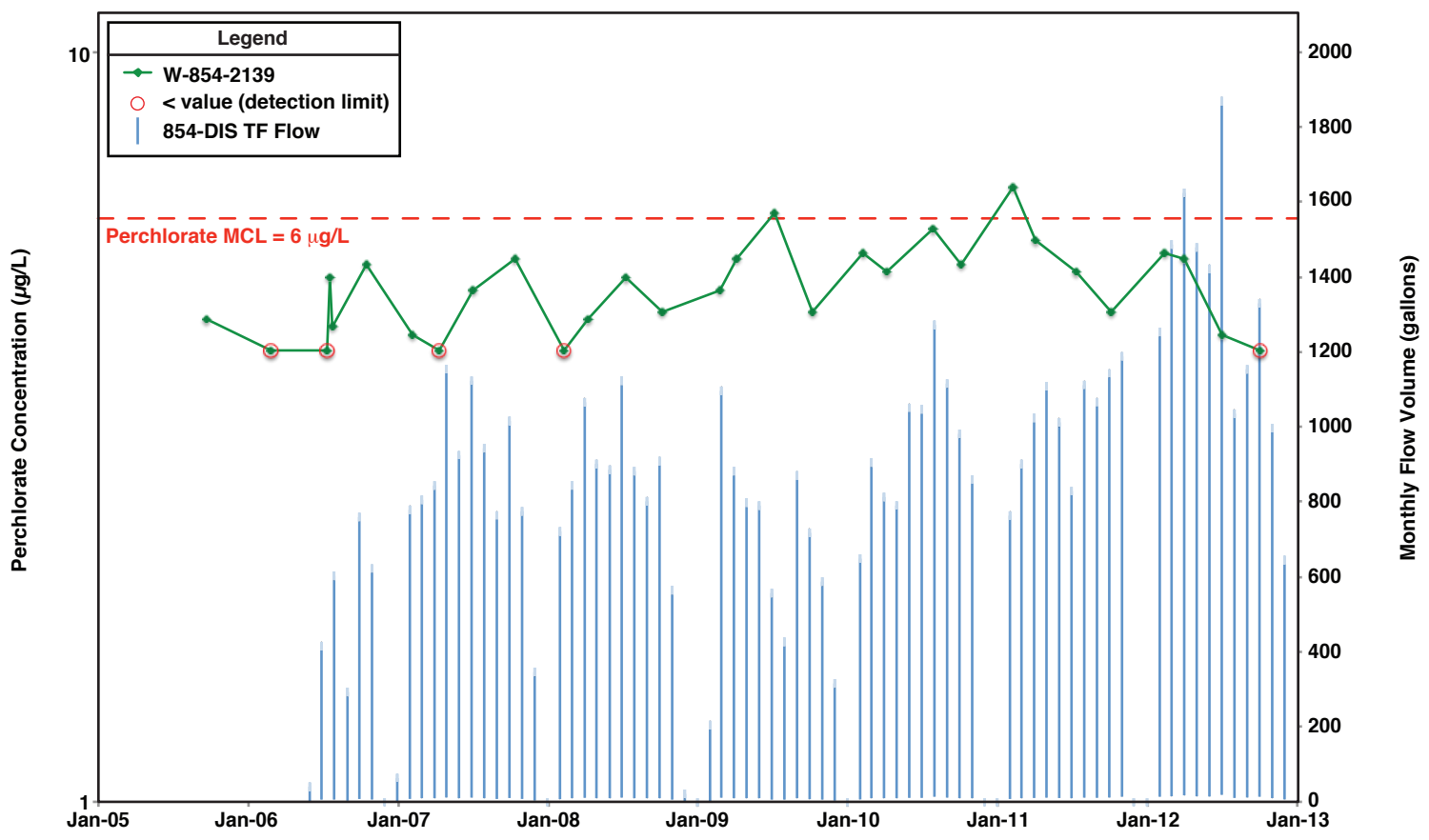
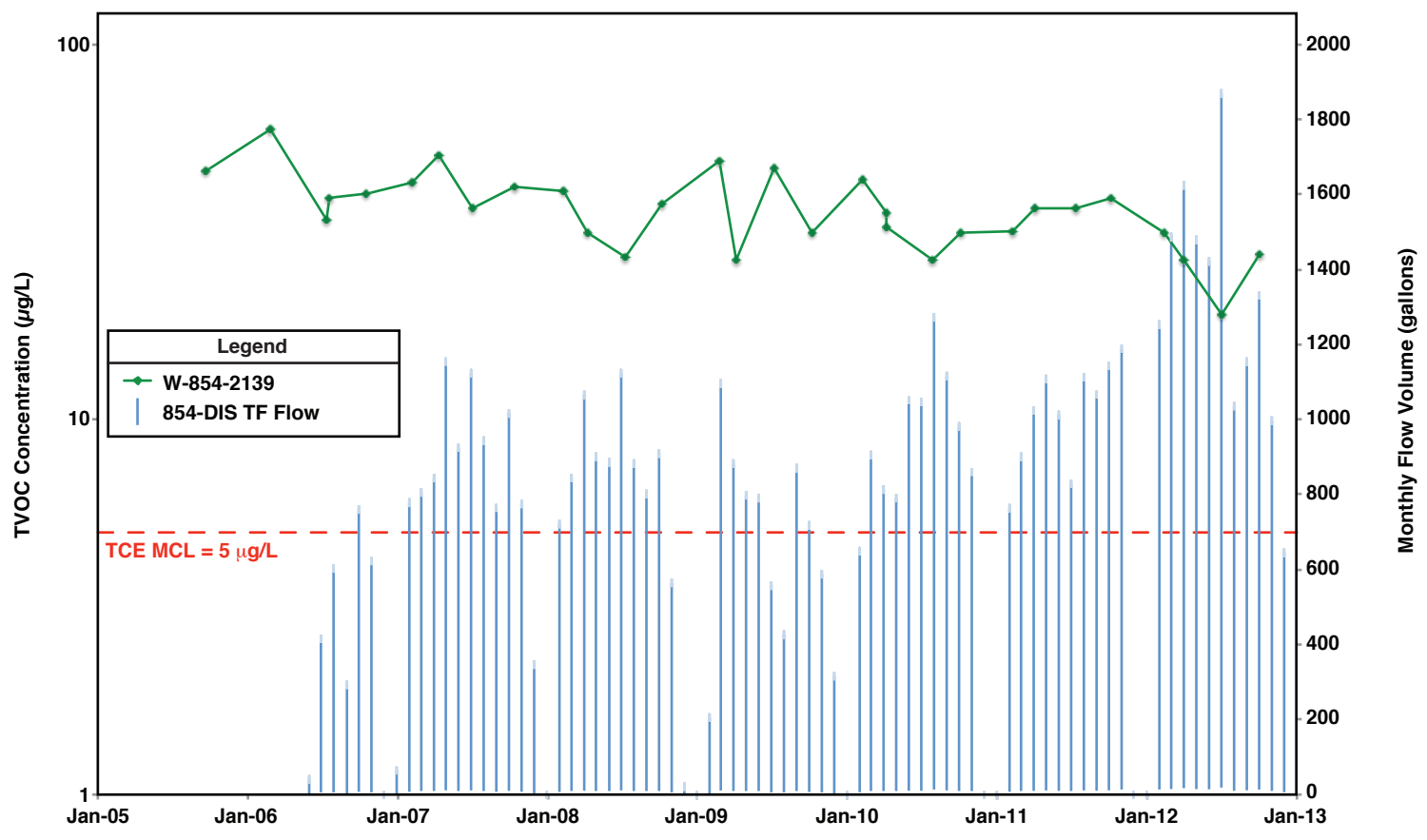
ERD-S3R-13-0045

Figure 20. Time-series plots of a) total VOCs, b) perchlorate, and (c) nitrate in ground water in the Building 854-Source Area extraction wells and monthly facility flow.



ERD-S3R-13-0046

Figure 21. Time-series plots of a) total VOCs, b) perchlorate, and c) nitrate in ground water in the Building 854-Proximal Area extraction wells and monthly facility flow.



ERD-S3R-13-0047

Figure 22. Time-series plots of a) total VOCs, b) perchlorate, and (c) nitrate in ground water in the Building 854-Distal Area extraction wells and monthly facility flow.

Tables

List of Tables

- Table 1. Actual annual costs for the Building 854 Operable Unit for fiscal years 2008 through 2012.
- Table 2. Description of Land Use Controls (institutional and engineered) for the Building 854 Operable Unit.

Table 1. Actual annual costs for the Building 854 Operable Unit for fiscal years 2008 through 2012.

Fiscal Year	Annual Budget	Actual Annual Cost
2008	614,246	468,655 ^a
2009	665,367	414,562 ^a
2010	551,395	471,770 ^a
2011	683,164	457,220 ^a
2012	752,048	455,317 ^b

Notes:

^a The Building 854 Operable Unit was under budget due to lower than expected operations, maintenance, and optimization costs.

^b The Building 854 Operable Unit was under budget due to the assessment and upgrade of Building 854-Proximal being deferred to fiscal year 2013.

Table 2. Description of Land Use Controls (institutional and engineered) for the Building 854 Operable Unit.

Land use control performance objective and duration	Risk necessitating institutional/land use control	Land use controls and implementation mechanism
Prevent water-supply use/consumption of contaminated ground water until ground water cleanup standards are met.	VOCs, nitrate, and perchlorate concentrations in ground water exceeding cleanup standards.	<p>There are no existing or planned water-supply wells in the Building 854 Operable Unit. Any proposed well drilling activities would be submitted to the LLNL Work Induction Board, and are reviewed by LLNL Environmental Restoration to ensure that new water-supply wells are not located in areas of ground water contamination.</p> <p>Prohibitions on drilling water-supply wells in areas of ground water contamination will be incorporated into an appropriate LLNL institutional planning document.</p> <p>Contamination is limited to onsite ground water and modeling indicates the plumes will not migrate offsite. Therefore, land use controls are not needed to prevent offsite water-supply use/consumption of contaminated ground water.</p>
Control excavation activities to prevent onsite worker exposure to VOCs in subsurface soil until it can be verified that concentrations do not pose an exposure risk to onsite workers.	Potential exposure to VOCs at depth in subsurface soil at the Building 854 Complex ^a .	All proposed excavation activities must be cleared through the LLNL Work Induction Board and require an excavation permit. The Work Induction Board coordinates with the LLNL Environmental Restoration Department to identify if there is a potential for exposure to contaminants in the proposed construction areas. If a potential for contaminant exposure is identified, LLNL Hazards Control ensures that hazards are adequately evaluated and necessary controls identified and implemented prior to the start of work. The Work Induction Board including the LLNL Environmental Analyst will also work with the Program proposing the construction project to determine if the work plans can be modified to move construction activities outside of areas of contamination.

Table 2. Description of Land Use Controls (institutional and engineered) for the Building 854 Operable Unit. (Continued)

Land use control performance objective and duration	Risk necessitating institutional/land use control	Land use controls and implementation mechanism
Maintain building occupancy restriction to prevent onsite site worker inhalation exposure to VOCs inside Buildings 854A and 854F and outside Building 854F until annual risk re-evaluation indicates that the risk is less than 10^{-6} .	Pre-remediation risks of 1×10^{-6} and 9×10^{-6} for onsite workers from inhalation of VOCs volatilizing from subsurface soil into ambient air inside Buildings 854A and 854F, respectively and 1×10^{-5} for onsite workers from inhalation of VOC volatilizing into outdoor air in the vicinity of Building 854F.	<p>Building 854F was demolished in 2005 removing the indoor air exposure pathway, therefore this institutional/land use control is no longer needed to prevent onsite worker exposure to VOCs in indoor air.</p> <p>The inhalation risks associated with outdoor air in the vicinity of Building 854F and Building 854A indoor air have been successfully reduced to less than 10^{-6} since 2004 and 2006, respectively, through ground water extraction and treatment, therefore this institutional/land use control is no longer needed to prevent onsite worker exposure to VOCs in Building 854F outdoor air and Building 854A indoor air.</p>
Maintain land use restrictions at the former Building 855 lagoon until remediation of PCB-, dioxin-, and furan-contaminated soil reduces the risk to onsite workers to less than 10^{-6} .	A pre-remediation risk of 1×10^{-6} was identified for onsite workers inhalation or ingestion of resuspended particulates and dermal contact with PCBs, and dioxin and furan compounds in surface soil at the former Building 855 lagoon.	In 2005, PCB-, dioxin-, and furan-contaminated soil in the former Building 855 lagoon was excavated for offsite disposal as a remedial action. As a result, the risk to onsite workers was reduced to less than 10^{-6} . Therefore, this institutional/land use control is no longer needed to prevent onsite worker exposure to PCBs, and dioxin and furan compounds in soil at the former Building 855 lagoon. However, a very limited volume of subsurface soil remains at a depth of approximately 8 feet below ground surface with PCBs, and dioxin and furan compound concentrations above residential preliminary remediation goals. The land transfer prohibition control described below prevents exposure under a residential land use.
Prohibit transfer of lands with unmitigated contamination that could cause potential harm under residential or unrestricted land use.	Potential exposure to contaminated waste and/or environmental media.	The Site 300 Federal Facility Agreement contains provisions that assure DOE will not transfer lands with unmitigated contamination that could cause potential harm. In the event that the Site 300 property is transferred in the future, DOE will execute a land use covenant at the time of transfer in compliance with Title 22 California Code of Regulations, Division 4.5, Chapter 39, Section 67391.1 and CERCLA 120(h).

Table 2. Description of Land Use Controls (institutional and engineered) for the Building 854 Operable Unit. (Continued)

Land use control performance objective and duration	Risk necessitating institutional/land use control	Land use controls and implementation mechanism
Prohibit transfer of lands with unmitigated contamination that could cause potential harm under residential or unrestricted land use. (continued)		Development will be restricted to industrial land usage. These restrictions will remain in place until and unless a risk assessment is performed in accordance with then current U.S. EPA risk assessment guidance and the DOE, U.S. EPA, DTSC, and RWQCB agree adequately shows that no unacceptable risk for residential or unrestricted land use is present. These restrictions will be incorporated an appropriate LLNL institutional planning document.

Notes:**CERCLA = Comprehensive Environmental Response, Compensation and Liability Act.****DOE = United States Department of Energy.****DTSC = California Department of Toxic Substances Control.****LLNL = Lawrence Livermore National Laboratory.****PCB = Polychlorinated biphenyl.****RWQCB = California Regional Water Quality Control Board.****U.S. EPA = United States Environmental Protection Agency.****VOCs = Volatile organic compounds.**

- ^a Risk for onsite worker exposure to VOCs at depth in subsurface soil during excavation activities was not calculated as this was not considered a long-term exposure scenario. As a result, land use controls based on the potential exposure to VOCs in subsurface soil during excavation activities conservatively assume that the VOCs in subsurface soil may pose a risk to human health.

Attachments

List of Attachments

- Attachment A. Evidence of Denitrification in Building 854 Operable Unit Ground Water.
- Attachment B. Building 854 Operable Unit Five-Year Review Inspection Checklist.

Attachment A

Evidence of Denitrification in Building 854

Operable Unit Ground Water

Attachment A

Evidence of Denitrification in Building 854 Operable Unit Ground Water

A-1. Introduction

Nitrate has been detected in Building 854 Operable Unit (OU) ground water at concentrations exceeding the 45 milligrams per liter (mg/L) Maximum Contaminant Level (MCL) cleanup standard and is identified as a secondary Contaminant of Concern (COC). During 2012, ground water samples from five Building 854 OU wells exceeded the 45 mg/L MCL. The wells with nitrate concentrations exceeding the 45 mg/L MCL are located near Building 854-Source (854-SRC) or Building 858 (Figures 12 and 20). There are septic systems in both of these areas that may be the source of the elevated nitrate concentrations.

The three wells located in the 854-SRC area contain nitrate at concentrations that exceed its MCL are: One Quaternary landslide deposits (Qls)/ Lower member of the Neroly lower blue sandstone (Tnbs₁) hydrostratigraphic unit (HSU) monitor well W-854-05, and two deeper Tnbs₁/Tertiary Neroly Formation—lower siltstone/claystone member (Tnsc₀) HSU extraction wells W-854-02 and W-854-2611. Two wells in the Building 858 area also contain nitrate at concentrations that exceed its MCL. Well W-854-14, screened in the shallow Qls/Tnbs₁ HSU, has a nitrate concentration of 230 mg/L. This is the maximum nitrate concentration detected in the Building 854 OU ground water. Well W-854-45, screened in the deeper Tnbs₁/Tnsc₀ HSU, has a nitrate concentration of 48 mg/L. Nitrate concentrations for all wells in the Building 854 OU remain stable or are slightly decreasing with the exception of W-854-45, which exhibits a slightly increasing trend.

Samples for nitrate isotopic analysis and excess nitrogen measurement have been collected from twenty wells and springs in the Building 854 OU between 2002 and 2013. The data were analyzed to assess the assimilative capacity of these HSUs for nitrate reduction via denitrification.

A-2. Denitrification

Denitrification is a microbial process, utilizing either organic or inorganic substrates as electron donors, that reduces nitrate to nitrogen gas. Heterotrophic denitrifying bacteria utilize organic compounds and autotrophic denitrifying bacteria utilize inorganic compounds. Denitrifying bacteria are widespread and under the proper conditions can significantly reduce nitrate concentrations in ground water. Autotrophic denitrification has been shown to reduce nitrate concentrations to well below 2 mg/L in the High Explosive Process Area (Madrid et al., 2002 and Beller et al., 2004).

Measurements of the stable isotope composition of nitrate (delta nitrogen-15 [$\delta^{15}\text{N}$]-nitrate [NO_3] and delta oxygen-18 [$\delta^{18}\text{O}$]- NO_3) and the excess nitrogen concentration (greater than

atmospheric equilibrium) in ground water are used to provide evidence of denitrification. As the denitrification process proceeds, the isotopic composition of the remaining nitrate becomes more enriched (more positive $\delta^{15}\text{N-NO}_3$ and $\delta^{18}\text{O-NO}_3$) because bacteria preferentially utilize the lighter isotopes. Concurrently, the mass of excess nitrogen, N_2 , the end product, increases.

The presence of enriched isotopic compositions and excess N_2 in some samples of ground water from the Building 854 OU led to collection of additional samples. The data are reviewed here for evidence of denitrification in ground water in the Building 854 OU.

A-3. Methods of Analysis

The analysis of stable isotope compositions of nitrate, and measurement of the dissolved gas compositions used to determine excess nitrogen, was performed by Lawrence Livermore National Laboratory (LLNL). Samples for isotopic analysis of nitrate ($\delta^{15}\text{N-NO}_3$ and $\delta^{18}\text{O-NO}_3$) were analyzed following a version of the denitrifier method (Casciotti et al., 2002; Sigman et al., 2001; Singleton et al., 2005). In this method, a strain of denitrifying bacteria is used to reduce dissolved nitrate in water samples to nitrous oxide (N_2O) gas that can be analyzed for nitrogen and oxygen isotopic composition using an isotope ratio mass spectrometer (IRMS). In order to detect excess dissolved nitrogen produced by denitrification, dissolved concentrations of nitrogen (N_2) and argon (Ar) were analyzed by Membrane Inlet Mass Spectrometry (MIMS) as described in Kana et al. (1994). Excess N_2 was calculated based on the method of Beller et al. (2004).

A-4. Results and Discussion

Isotope and excess N_2 data from 20 wells and springs within the Building 854 OU collected between 2002 and 2013 are shown in Table A-1. Figures A-1, A-2, and A-3 show the data plotted as $\delta^{18}\text{O-NO}_3$ versus $\delta^{15}\text{N-NO}_3$, excess N_2 versus $\delta^{15}\text{N-NO}_3$, and total excess N_2 and nitrate (NO_3) concentrations per well, respectively.

In Figure A-1, which plots $\delta^{18}\text{O-NO}_3$ versus $\delta^{15}\text{N-NO}_3$, only two locations, well W-854-1731 (screened in the Tmss HSU) and Spring 11, plot outside of the range of nitrate isotopic compositions for fertilizer, soil, and manure and septic effluent defined by Kendall (1998). Assuming the original isotopic compositions of the nitrate from well W-854-1731 and Spring 11 were similar to the other Building 854 OU locations shown in the plot, they would follow a trend line with a slope similar to the denitrification trend line to reach their current isotopic compositions. The enriched isotopic compositions (both $\delta^{15}\text{N}$ and $\delta^{18}\text{O}$) of the nitrate in the samples from Spring 11 and well W-854-1731 and their relationship to the denitrification trend line indicate denitrification. Nitrate in water collected from Spring 10 has an isotopic composition that plots within the range of soil nitrate indicating no denitrification at this spring.

Figure A-2 plots excess N_2 (expressed as equivalent nitrate in mg/L) versus $\delta^{15}\text{N-NO}_3$. Greater amounts of excess N_2 and more positive $\delta^{15}\text{N-NO}_3$ values (the upper right corner of the plot) are evidence for denitrification. On the basis of $\delta^{15}\text{N-NO}_3$ greater than 10 parts per 1,000 (o/oo) and an excess N_2 content (expressed as equivalent nitrate in mg/L) of greater than 5 mg/L, only one of the wells sampled, W-854-1731 (screened in the Tmss HSU), exhibits clear evidence of denitrification. Wells W-854-15 (Qls/Tnbs₁), with a $\delta^{15}\text{N-NO}_3$ value of 11.5 o/oo

and an excess N_2 content of 5 mg/L, and W-854-1822 ($Tnbs_1/Tnsc_0$) with a $\delta^{15}N-NO_3$ value of 6.8 o/oo and an excess N_2 content of 9 mg/L exhibit some evidence for localized low magnitude denitrification in these HSUs.

Figure A-3 shows total nitrate (mg/L) and excess N_2 (expressed as equivalent nitrate in mg/L) for each well. Wells screened in the $Tnbs_1/Tnsc_0$ HSU are plotted from left to right in an order that follows the general ground water flow direction (northwest to southeast). Wells screened in other HSUs are located on the right side of the plot and labeled with their HSU designation. Several observations can be made regarding nitrate concentrations in ground water, relative proportions of nitrate and dissolved N_2 , and the distributions of nitrate and dissolved N_2 along the ground water flow path and with depth in the $Tnbs_1/Tnsc_0$ HSU. The combined sum of nitrate plus excess N_2 for each of the wells does not exceed the 45 mg/L MCL cleanup standard.

The majority of the wells in the $Tnbs_1/Tnsc_0$ HSU, with the exception of a few wells located near possible septic sources at the Building 854 source area and Building 858 Drop Tower (Figure 20), have nitrate concentrations below the 45 mg/L MCL, indicating that there are no significant anthropogenic sources of nitrate other than these two areas. Wells with nitrate concentrations exceeding 20 mg/L have smaller proportions of excess N_2 , 20% or less of the total nitrate and excess N_2 composition, whereas three wells with nitrate concentrations of less than 5 mg/L have higher proportions of excess N_2 , 80% or more of the total nitrate and excess N_2 composition. The presence of measurable excess N_2 relative to nitrate concentration indicates some low level denitrification (Figure A-1). The general decrease in nitrate concentration along the ground water flow path is likely a combination of some denitrification coupled with dispersion and diffusion.

There also appears to be some evidence that assimilative capacity for nitrate reduction increases with depth within the $Tnbs_1/Tnsc_0$. For example, near Building 854-Distal (854-DIS) (Figure 20), wells W-854-2139 and W-854-07 are screened at shallower depths ranging between 110 to 124 feet below ground surface and wells W-854-2115 and W-854-06 are screened deeper at depths ranging between 156 to 170 feet below ground surface within the $Tnbs_1/Tnsc_0$. The two shallower wells have nitrate concentrations exceeding 20 mg/L and the two deeper wells have nitrate concentrations less than 5 mg/L. The samples from wells W-854-2139 and W-854-2115 contain proportions of excess N_2 relative to total nitrate and excess N_2 of 21% and 80%, respectively. The samples from wells W-854-06 and W-854-07, collected in 2007, did not contain measureable excess N_2 concentrations. At this location, nitrate concentrations decrease with depth and the more recent samples collected in 2012 show that the proportion of excess N_2 to nitrate increases with depth. This suggests that conditions for denitrification are more favorable with increasing depth. Additionally, ground water from well W-854-1731, screened in the deeper $Tmss$ HSU, has a greater proportion of excess N_2 to nitrate, a low nitrate concentration, and an enriched nitrate isotopic composition (both $\delta^{15}N$ and $\delta^{18}O$) that clearly fits a denitrification trend.

A-5. Conclusions

The combined effects of the complex geologic and hydrogeologic conditions in the Building 854 OU and multiple sources of nitrate make interpretation of the nitrate and excess N_2 data from the wells screened in the $Tnbs_1/Tnsc_0$ HSU challenging. The distribution of nitrate

concentrations in this HSU, both laterally and vertically, can best be explained by some capacity for denitrification coupled with dilution due to dispersion and diffusion.

Strong evidence of denitrification was exhibited in ground water from Tmss well W-854-1731. This evidence includes enriched nitrate isotopic composition, low nitrate concentrations, and high proportion of excess N_2 to nitrate concentration. Further analysis is needed to demonstrate whether this HSU exhibits a widespread assimilative capacity for nitrate reduction.

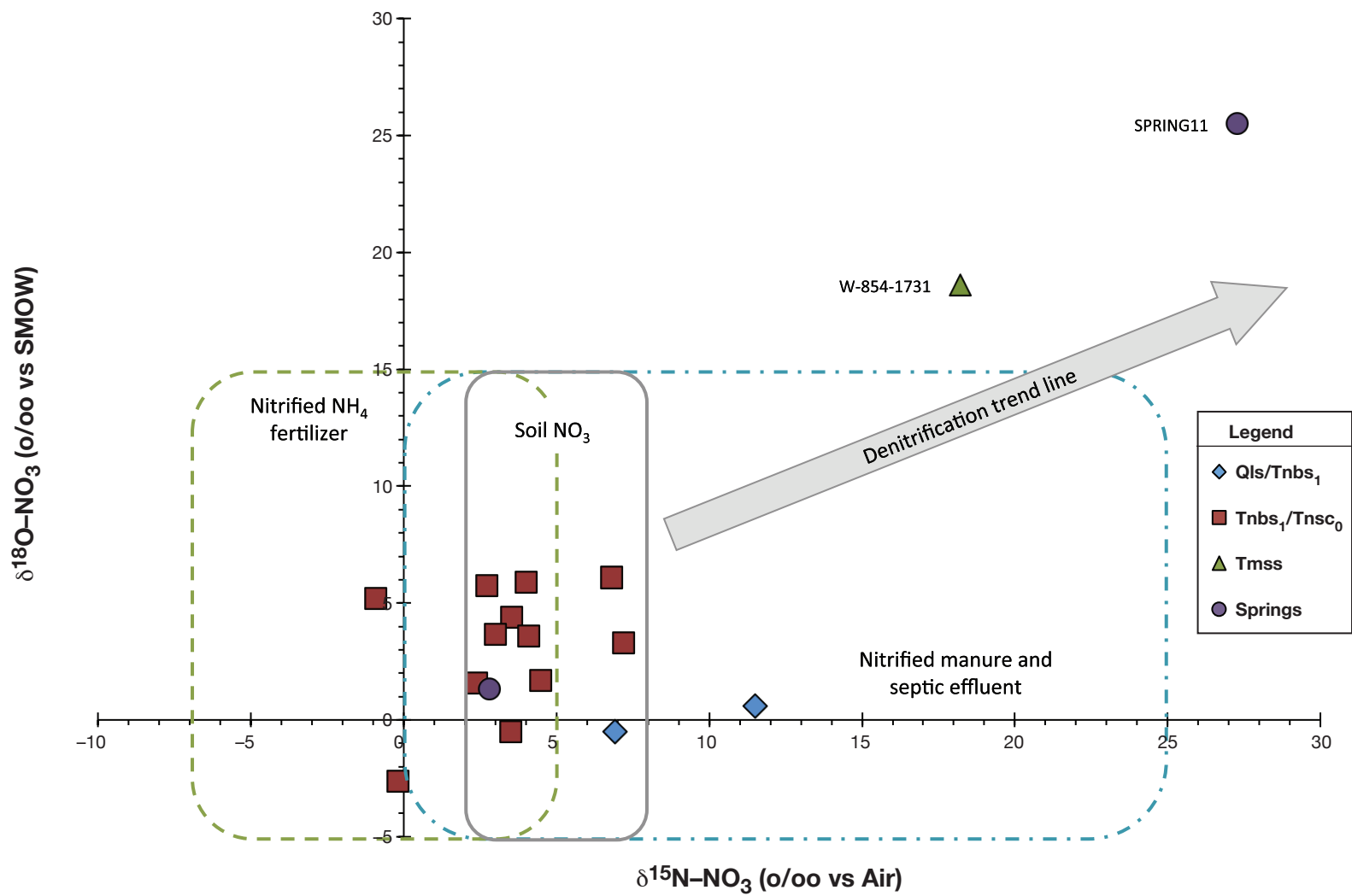
The enriched nitrate isotopic composition of the Spring 11 sample clearly indicates denitrification, although this may be the result of local surface processes rather than denitrification of ground water along a subsurface ground water flow path.

A-6. References

- Beller, H. R., Madrid, V., Hudson, G. B., McNab, W. W., and Carlsen, T., 2004. Biogeochemistry and natural attenuation of nitrate in groundwater at an explosives test facility. *Applied Geochemistry* 19, 1483-1494.
- Casciotti, K. L., Sigman, D. M., Hastings, M. G., Bohlke, J. K., and Hilkert, A., 2002. Measurement of the oxygen isotopic composition of nitrate in seawater and freshwater using the denitrifier method. *Analytical Chemistry* 74, 4905-4912.
- Kana, T. M., Darkangelo, C., Hunt, M. D., Oldham, J. B., Bennett, G. E., and Cornwell, J. C., 1994. Membrane inlet mass spectrometer for rapid high precision determination of N₂, O₂, and Ar in environmental water samples. *Analytical Chemistry* 66, 4166-4170.
- Kendall, C., 1998. Tracing nitrogen sources and cycling in catchments. In: Kendall, C. and McDonnell, J. J. Eds.), *Isotope Tracers in Catchment Hydrology*. Elsevier, New York.
- Madrid, V. M., L. Ferry, A. Ritcey, J. Valett, and M. Verce (2002), *Interim Remedial Design for the High Explosives Process Area Operable Unit at Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-147095).
- Sigman, D. M., Casciotti, K.L., Andreani, M., Barford, C., Galanter, M., and Bohlke, J. K., 2001. A bacterial method for the nitrogen isotopic analysis of nitrate in seawater and freshwater. *Analytical Chemistry* 73, 4145-4153.
- Singleton, M. J., Woods, K. N., Conrad, M. E., Depaolo, D. J., and Dresel, P. E., 2005. Tracking sources of unsaturated zone and groundwater nitrate contamination using nitrogen and oxygen stable isotopes at the Hanford Site, Washington. *Environmental Science & Technology* 39, 3563-3570.

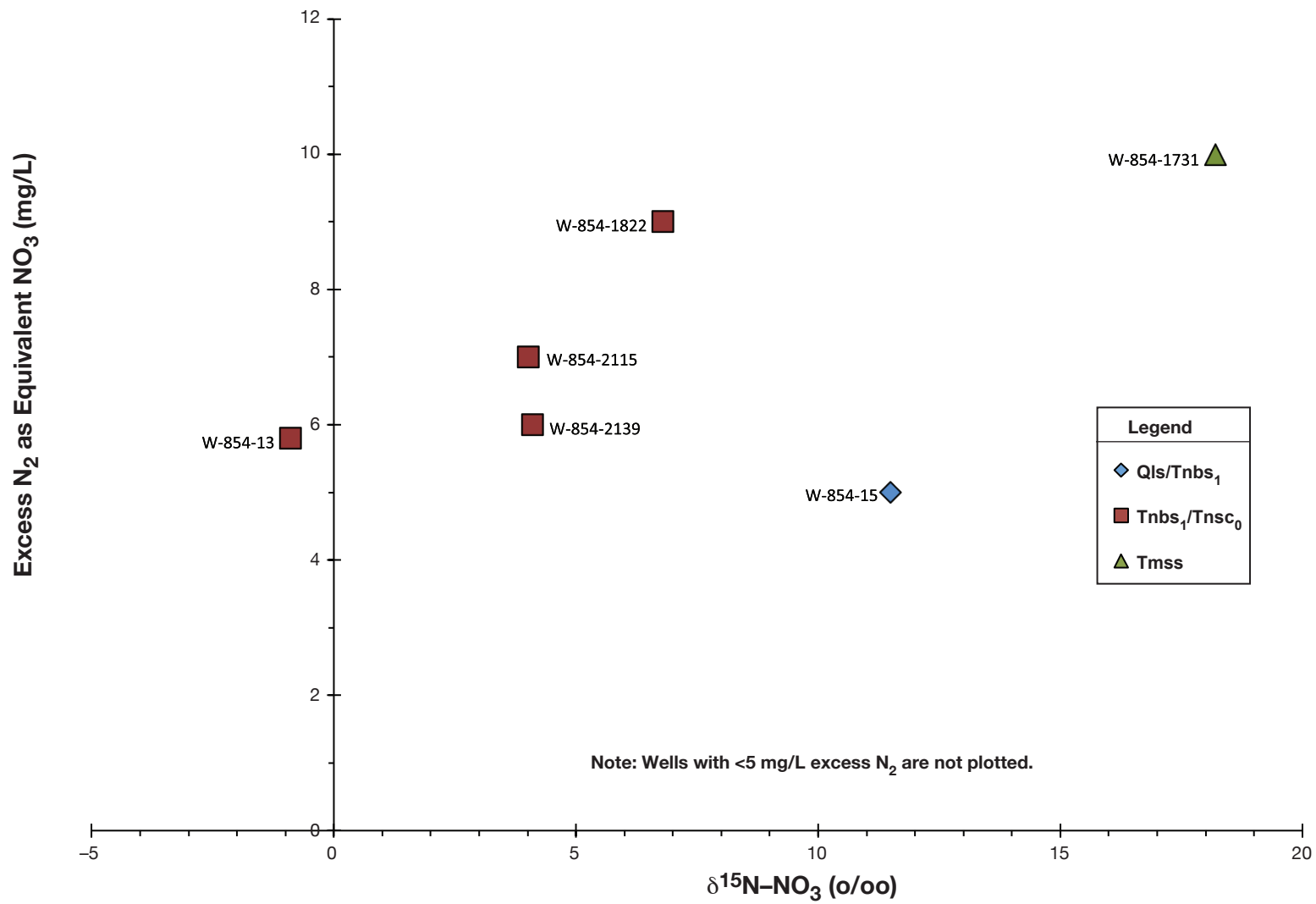
A-7. Acronyms and Abbreviations

$\delta^{15}\text{N}$	Delta nitrogen-15
$\delta^{18}\text{O}$	Delta oxygen-18
854-DIS	Building 854-Distal
854-SRC	Building 854-Source
Ar	Argon
COC	Contaminant of Concern
HSU	Hydrostratigraphic Unit
IRMS	Isotope ratio mass spectrometer
LLNL	Lawrence Livermore National Laboratory
MCL	Maximum Contaminant Level
MIMS	Membrane Inlet Mass Spectrometry
mg/L	Milligrams per liter
N_2	Nitrogen
N_2O	Nitrous oxide
NO_3	Nitrate
o/oo	Parts per 1,000
OU	Operable Unit
Qls	Quaternary landslide deposits
Tnbs ₁	Lower member of the Neroly lower blue sandstone
Tnsc ₀	Tertiary Neroly Formation—lower siltstone/claystone member



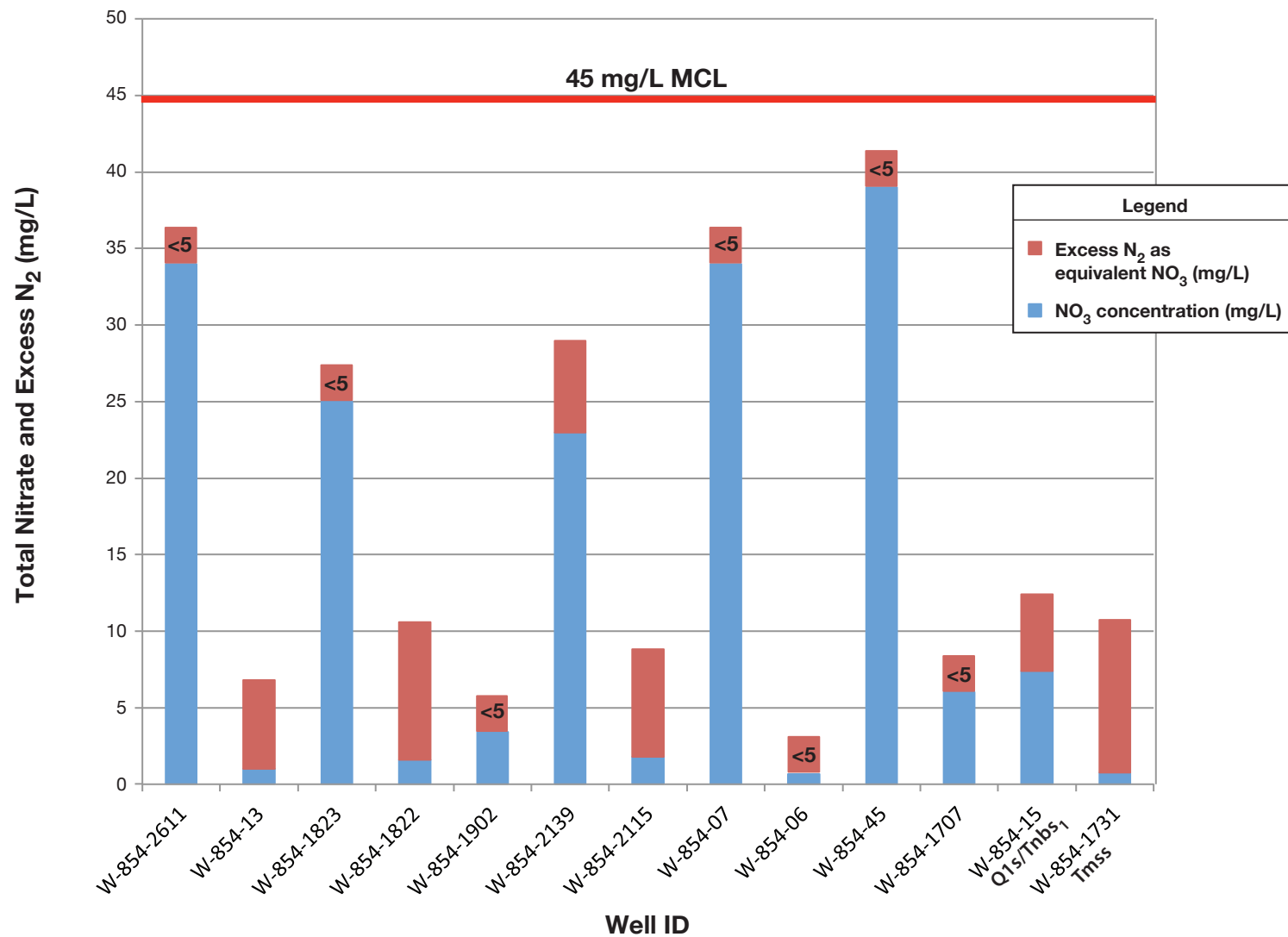
ERD-S3R-13-0041

Figure A-1. $\delta^{18}\text{O}$ vs $\delta^{15}\text{N}$ plot of nitrate in ground water samples from Building 854 Operable Unit wells.



ERD-S3R-13-0040

Figure A-2. Excess nitrogen (N₂) vs δ¹⁵N of nitrate plot of ground water samples from Building 854 Operable Unit wells.



ERD-S3R-13-0039

Figure A-3. Total nitrate and excess nitrogen (N₂) content of ground water samples from Building 854 Operable Unit wells (all wells screened in the Tnbs₁/Tnsc₀ HSU unless otherwise noted).

Table A-1. Nitrate concentration, nitrate isotope, and excess nitrogen data for Building 854 Operable Unit ground water.

Field Location	HSU	Nitrate (mg/L)	Sample Date	Delta ¹⁵ N (o/oo)	Delta ¹⁸ O (o/oo)	Sample Date	Excess Nitrogen (as equivalent NO ₃ [(mg/L)])	Sample Date	Evidence for Denitrification ^a
W-854-05	Qls/Tnbs ₁	63	8/13/02	2.74	1.27	8/13/02	No Data	NA	NA
W-854-14	Qls/Tnbs ₁	260	5/16/07	6.9	-0.5	11/7/07	No Data	NA	NA
W-854-15	Qls/Tnbs ₁	7.4	5/22/12	11.5	0.6	1/22/13	5	1/22/13	YES?
W-854-02	Tnbs ₁ /Tnsc ₀	56	8/8/02	3.53	4.41	8/13/02	No Data	NA	NA
W-854-03	Tnbs ₁ /Tnsc ₀	47	8/8/02	3	3.68	8/13/02	No Data	NA	NA
W-854-06	Tnbs ₁ /Tnsc ₀	0.68	5/22/07	No Data	No Data	NA	<5.0	8/14/07	NO
W-854-07	Tnbs ₁ /Tnsc ₀	34	5/22/07	2.4	1.6	8/14/07	<5.0	8/14/07	NO
W-854-13	Tnbs ₁ /Tnsc ₀	1	6/18/07	-0.9	5.2	8/15/07	5.8	8/15/07	NO
W-854-45	Tnbs ₁ /Tnsc ₀	39	8/13/02	2.7	5.74	8/13/02	<5.0	8/26/02	NO
W-854-1707	Tnbs ₁ /Tnsc ₀	6	6/4/08	-0.2	-2.6	8/15/07	<5.0	8/15/07	NO
W-854-1822	Tnbs ₁ /Tnsc ₀	1.6	5/21/12	6.8	6.1	1/22/13	9	1/22/13	NO?
W-854-1823	Tnbs ₁ /Tnsc ₀	25	5/21/07	3.5	-0.5	8/14/07	<5.0	8/14/07	NO
W-854-1902	Tnbs ₁ /Tnsc ₀	3.4	5/22/07	7.2	3.3	8/14/07	<5.0	8/14/07	NO
W-854-2115	Tnbs ₁ /Tnsc ₀	1.8	5/22/12	4	5.9	7/24/12	7	1/22/13	NO
W-854-2139	Tnbs ₁ /Tnsc ₀	23	10/2/12	4.1	3.6	1/22/13	6	1/22/13	NO
W-854-2611	Tnbs ₁ /Tnsc ₀	34	6/3/10	4.5	1.7	6/3/10	<5.0	6/3/10	NO
W-854-1701	Tnsc ₀	<0.5	5/21/12	No Data	No Data	NA	3	1/22/13	NA
W-854-1731	Tmss	0.74	5/23/12	18.2	18.6	1/22/13	10	1/22/13	YES
SPRING10	Tnbs ₁ /Tnsc ₀	0.44	5/25/07	2.8	1.3	8/15/07	<5.0	8/15/07	NO
SPRING11	Tnbs ₁ /Tnsc ₀	0.1	5/25/07	27.3	25.5	8/15/07	<5.0	8/15/07	YES

Notes appear on the following page.

**Table A-1. Nitrate concentration, nitrate isotope, and excess nitrogen data for Building 854 Operable Unit ground water.
(Continued)****Notes:**

HSU = Hydrostratigraphic unit.

mg/L = Milligrams per liter.

 ^{15}N = Nitrogen-15 isotope.

NA = Not applicable.

 NO_3 = Nitrate. ^{18}O = Oxygen-18 isotope.

^a Positive evidence for denitrification is a Delta ^{15}N value of > 10 o/oo (per mil) and excess nitrogen concentration of > 5 mg/L (as equivalent nitrate). Wells W-854-15 and W-854-1822 with Yes? and No? responses respectively indicate borderline results.

Attachment B

Building 854 Operable Unit

Five-Year Review Inspection Checklist

**Building 854 Operable Unit
Five-Year Review Site Inspection Checklist
Lawrence Livermore National Laboratory (LLNL) Site 300**

I. SITE INFORMATION

Site Name: Building 854 Operable Unit (OU), LLNL Site 300

Date of inspection: May 9, 2012

Location and Region: Corral Hollow Road, San Joaquin/Alameda County, California

EPA Region: 9

EPA ID: CA 2890090002

Agency Leading the Five-Year Review: U.S. Department of Energy (DOE) – National Nuclear Security Administration (NNSA) Livermore Field Office (LFO)

Weather/Temperature: The climate of Site 300 is semiarid and windy with wide temperature variations.

Remedy Includes:

- Monitoring to evaluate the effectiveness of the remedial action in achieving cleanup standards.
- Risk and hazard management (including institutional and administrative controls) to prevent onsite workers exposure to volatile organic compounds (VOCs) volatilizing from subsurface soil and impacts to onsite workers until risk and hazard is mitigated through active remediation.
- Extracting and treating VOCs, perchlorate, and nitrate in ground water and soil vapor to mitigate unacceptable VOC inhalation risk for onsite workers, prevent further impacts to ground water and offsite plume migration, and reduce contaminant concentrations in ground water to cleanup standards.

Site Map: See Building 854 OU Five-Year Review Figure 1.

II. INTERVIEWS

1. O&M Site Manager

Lawrence Livermore National Security (LLNS), LLC (M&O Contractor to DOE): Leslie Ferry, Site 300 Environmental Restoration (ER) Program Leader.

Remarks: As there is a full-time presence of the DOE-LFO Remedial Project Manager (RPM) and the LLNS Site 300 ER Program Leader, Site 300 ER Field Operations Manager, and the Building 854 OU treatment facility operator at the site, the oversight, inspections, evaluations, and discussions of the Building 854 OU remedy are ongoing. Remedy performance, facility operations, and any related issues are managed in real-time in collaboration with the Field Operations Manager, the facility operator, and full-time staff from the Site 300 ER Field Operations, Hydrogeology, Engineering, Water Quality Sampling & Analysis Teams. As such, there was no single “interview” of DOE or LLNS O&M Managers or interview results that can be referenced. The information contained within this inspection checklist is a compilation of this and other DOE-LFO RPM routine inspections, evaluations, and discussions with the LLNS Site 300 ER Program Leader and staff regarding the Building 854 OU remedy and treatment facility. In addition, DOE/LLNS presents and discusses any treatment facility operations and maintenance (O&M) or other remedy related issues with the regulatory agencies on an ongoing basis via monthly regulatory RPM project updates and meetings, and in the semi-annual and annual compliance monitoring reports.

2. O&M Staff

Lawrence Livermore National Security (LLNS), LLC (M&O Contractor to DOE):

- Steve Orloff, Site 300 ER Field Operations Manager.
- Joe Faria, Operator - Building 854 ground water extraction and treatment systems.

Remarks: As there is a full-time presence of the DOE-LFO RPM, LLNS Site 300 ER Program Leader, Site 300 ER Field Operations Manager, and Building 854 OU treatment facility operator at the site, the oversight, inspections, evaluations, and discussions of the Building 854 OU remedy are ongoing. Facility operations and any related issues are managed in real-time by the entities listed above in collaboration with full-time staff from the Site 300 ER Field Operations, Hydrogeology, Engineering, Water Quality Sampling & Analysis Teams. As such, there was no single “interview” of O&M staff or interview results that can be referenced. The information contained within this inspection checklist is a compilation of this and

other DOE-LFO RPM routine inspections, evaluations, and discussions regarding the Building 854 OU remedy and treatment facility.

3. Local Regulatory Authorities and Response Agencies (i.e., State and Tribal offices, emergency response office, police department, office of public health or environmental health, zoning office, recorder of deeds, or other city and county offices, etc.) Fill in all that apply.

Not applicable.

III. ON-SITE DOCUMENTS & RECORDS VERIFIED

1. O&M Documents

O&M manual:	Readily available and up-to-date
As-built drawings:	Readily available and up-to-date
Maintenance logs:	Readily available and up-to-date

Remarks: As-built drawings for the Building 854 OU treatment facilities are maintained in the LLNL Environmental Restoration Department files. The Building 854 OU treatment facilities consist of the Building 85-Source (854-SRC), Building 854-Proximal (854-PRX), and Building 854-Distal (854-DIS). The Building 854 OU treatment facilities maintenance activities are recorded in a facility-specific logbook maintained by the facility operator. In addition, facility maintenance activities are discussed in monthly Project Updates submitted to the regulatory RPMs, at regular RPM meetings, and in the semi-annual and annual Site-Wide Compliance Monitoring Reports.

2. Site-Specific Health & Safety Plan

Site-Specific Health & Safety Plan:	Readily available and up-to-date
Contingency plan/emergency response plan:	Readily available and up-to-date

Remarks: Site-specific health and safety information for Environmental Restoration activities is contained in the "Site Safety Plan for LLNL CERCLA Investigations at Site 300." Activity-specific hazards and controls are contained in the LLNL Environmental Restoration Integration Work Sheets. Activities conducted at LLNL Site 300 are also conducted in accordance with the LLNL Environment, Safety, and Health Plan.

The contingency plan, including contingency actions in the event of natural disasters or other emergencies, for the Building 854 OU remedial action is included in the

“Compliance Monitoring Plan and Contingency Plan for the Environmental Restoration at LLNL Site 300.”

Emergency responses are also contained in Volume II, Part 22 of the LLNL Environment, Safety, and Health Plan and the Self-Help Plans.

3. O&M and OSHA Training Records

O&M and OSHA Training Records Readily available and up-to-date

Remarks: Operation and maintenance activities associated with the Building 854 OU ground water and soil vapor extraction and treatment systems are recorded and maintained in the facility-specific logbooks maintained by the facility operators. In addition, O&M activities are discussed in monthly Project Updates submitted to the regulatory RPMs, at regular RPM meetings, and in the semi-annual and annual Site-Wide Compliance Monitoring Reports.

OSHA HAZWOPER training for LLNS ER Department staff is up-to-date. Training Records for LLNS ER Department staff are maintained electronically in the LLNL Laboratory Training Records and Information (LTRAIN) System.

4. Permits and Service Agreements

Air discharge permit:	Readily available and up-to-date
Effluent discharge permit:	Not applicable*
Waste Disposal:	Readily available and up-to-date
Other permits:	Not applicable

Remarks:

Air discharge permit: The air permit to operate for the Building 854 soil vapor treatment system issued by the San Joaquin Valley Air Pollution Control District (SJVAPCD) is maintained at the Building 854 treatment facility, and in the files at Building 543.

***Effluent discharge:** Effluent discharge limits are contained in the Substantive Requirements for Waste Discharge issued by the Regional Water Quality Control Board (RWQCB)-Central Valley Region and in the Site-Wide Record of Decision (ROD) for LLNL Site 300. The RWQCB Substantive Requirements and Site-Wide ROD are maintained in the administrative record at LLNL; the Site-Wide ROD is also available on-line at www-erd.llnl.gov/library/index.html

Waste Disposal: Spent treatment media is stored at a permitted onsite storage facility (EPA ID No CA2890090002) by the LLNL Radioactive and Hazardous Waste Department prior to shipment offsite to a permitted disposal facility.

Other permits: None.

5. Gas Generation Records

Gas Generation Records: Not applicable

6. Settlement Monument Records

Settlement Monument Records: Not applicable

7. Ground water Monitoring Records

Ground water Monitoring Records: Readily available and up-to-date

Remarks: Ground water monitoring records for the Building 854 OU are maintained in the LLNL ER Department's Taurus Environmental Information Management System (TEIMS) database. The ground water compliance monitoring results are presented in the semi-annual and annual Site-Wide Compliance Monitoring Reports that are sent to the U.S. EPA, the RWQCB, and the California Department of Toxic Substances Control (DTSC), and are available on-line at www-erd.llnl.gov/library/index.html

8. Leachate Extraction Records:

Leachate Extraction Records: Not applicable

9. Discharge Compliance Records

Air: Readily available and up-to-date
Water: Readily available and up-to-date

Remarks:

Air: Air discharge monitoring results for the Building 854 soil vapor treatment system are recorded in the Building 854 treatment facility logbook. The SJVAPCD conducts annual inspections to ensure compliance with the air permit discharge requirements. The air permit compliance status is also reported in the monthly RPM Project Updates.

Water (effluent): The Building 854 OU ground water extraction and treatment systems effluent discharge compliance records are maintained in the LLNL ER Department's TEIMS data base, and are presented in the semi-annual and annual Site-Wide Compliance Monitoring Reports that are sent to the U.S. EPA, the RWQCB, and DTSC, and are available on-line at www-erd.llnl.gov/library/index.html

10. Daily Access/Security Logs

Daily Access/Security Logs: Readily available and up-to-date

Remarks: The Building 854 OU treatment facilities maintenance activities are recorded in a facility-specific logbook maintained by the facility operators. Site 300 is a restricted access facility and badging and clearance that must be presented to a security force guard is required to gain entry to the site.

IV. O&M COSTS

1. O&M Organization

Contractor for Federal Facility: The Environmental Restoration Department of Lawrence Livermore National Security, LLC; the M&O contractor for the U.S. DOE at LLNL.

2. O&M Cost Records

O&M Cost Records: Readily available and up-to-date
Funding mechanism in place

Remarks: The actual annual costs for the Building 854 OU during the review period (2008-2012) are presented in Table 1 of the Five-Year Review. LLNS Environmental Restoration Department provides monthly reports to the DOE-LFO RPM on Building 854 OU restoration planned and actual costs with explanations/justifications of any cost variances.

3. Unanticipated or Unusually High O&M Costs During the Review Period

Describe costs and reasons: No unanticipated or unusually high O&M costs were incurred during the review period. As described in Table 1 of the Building 854 Five-Year Review, costs for the Building 854 OU were consistently under budget for the

review period due to lower than expected operations, maintenance, and optimization costs.

V. ACCESS AND INSTITUTIONAL CONTROLS

Applicable

A. Fencing

1. Fencing Damaged

Fencing damaged location:
Gate secured:

Fencing in good condition
Yes

Remarks: LLNL Site 300 is a restricted access facility that is surrounded by fencing to prevent unauthorized access.

B. Other Access Restrictions

2. Signs and Other Security Measures

Signs and Other Security Measures In place

Yes

Remarks: LLNL Site 300 is a restricted access facility that is surrounded by fencing and has a full-time security force to prevent unauthorized access to the site.

C. Institutional Controls (ICs)

1. Implementation and Enforcement

Site conditions imply ICs not properly implemented:
Site conditions imply ICs not being fully enforced:

No
No

Type of monitoring (e.g., self-reporting, drive by):
Frequency:

Physical inspection

Physical ICs are inspected annually.
ICs are reviewed annually for adequacy and protectiveness.

Responsible party/agency: U.S DOE
Contact Name: Claire Holtzapple

Title: DOE-LFO Site 300 Environmental Restoration RPM
Phone No.: 925/422-0670

IC Inspection Date: 12/4/12

Reporting is up-to-date: Yes
Reports are verified by the lead agency: Yes
Specific requirements in deed or decision document have been met: Yes
Violations have been reported: Not Applicable
Other problems or suggestions: None

Remarks: Refer to Section 4.4. (Institutional Controls) of the Building 854 OU Five-Year Review for further details on institutional controls in the Building 854 OU.

2. Adequacy

ICs are adequate: Yes

Remarks: Refer to Section 4.4. (Institutional Controls) of the Building 854 Five-Year Review for further details on institutional controls in the Building 854 OU.

D. General

1. Vandalism/trespassing

Vandalism/trespassing: No vandalism evident

Remarks: LLNL Site 300 is a restricted access facility that is surrounded by fencing and has a full-time security force to prevent unauthorized access to the site.

2. Land Use Changes Onsite

Land Use Changes Onsite: None

Remarks: There have been no changes in land, building, or ground water use in the Building 854 OU since the Site-Wide Record of Decision and none are anticipated. The Building 854 Complex (Buildings 854A, B, C, D, E, F, G, H, J, and V) was used to test the stability of weapons and weapon components under various environmental conditions and mechanical and thermal stresses. In 2005, Buildings 854B, C, D, E, F, G, and J were decontaminated and demolished. Building 854H and V are still used as HE magazines. HE processing and machining operations continue at Building 855.

In 2011, Building 854A was periodically occupied and used as a control room for large explosive experiments conducted at Building 851.

At Site 300, ground water is used for a variety of needs including cooling towers, HE processing, and fire suppression. Bottled water is the primary source of onsite drinking water, however potable ground water from onsite water-supply Well 20, located in the High Explosives Process Area OU, is available as necessary for potable supply. Well 18, also located in the southeast part of the High Explosives Process Area OU is used as a backup water-supply well. Site 300 is currently scheduled to transition to Hetch Hetchy water as its primary onsite water supply. Refer to Section 3.2. (Land and Resource Use) of the Building 854 OU Five-Year Review for further details on land use in the Building 854 OU.

3. Land Use Changes Offsite

Land Use Changes Offsite:

Not applicable

Remarks: Land use adjacent to the site boundary closest to the Building 854 OU consists of private rangeland and the Carnegie State Vehicular Recreation Area (SVRA). The nearest major population center (Tracy, California) is 8.5 miles to the northeast. While there is offsite development proposed adjacent to and north of Site 300 (the Tracy Hills Development), this development does not border the Building 854 OU. There is no known planned modification or proposed development of the offsite land adjacent to the OU.

VI. GENERAL SITE CONDITIONS

A. Roads

1. Roads Damaged

Roads damaged location:

Roads adequate

Remarks: The Building 854 OU treatment facilities and wells are accessed by roads maintained by the LLNL Site 300 management.

B. Other Site Conditions

Remarks: The Building 854 OU treatment facilities and wells are maintained in good condition by the LLNL Site 300 management.

VII. LANDFILL COVERS	Not applicable
-----------------------------	----------------

VIII. VERTICAL BARRIER WALLS	Not applicable
-------------------------------------	----------------

IX. GROUND WATER/SURFACE WATER REMEDIES	Applicable
--	------------

A. Groundwater Extraction Wells, Pumps, and Pipelines	Applicable
--	------------

1. Pumps, Wellhead Plumbing, and Electrical

Good condition:	Yes
All required wells properly operating:	Yes

Remarks: The ground water extraction wells are inspected weekly and are in good condition and operating properly.

2. Extraction System Pipelines, Valves, Valve Boxes, and Other Appurtenances

Good condition:	Yes
-----------------	-----

Remarks: All extraction system pipelines and valves are inspected weekly and are in good condition.

3. Spare Parts and Equipment

Readily available:	Yes
Good condition:	Yes

Remarks: Spare parts for routine equipment maintenance are readily available and in good condition.

B. Surface Water Collection Structures, Pumps, and Pipelines	Not applicable
---	----------------

C. Treatment System

Applicable

1. Treatment Train (check components that apply)

Metals removal:	Not applicable
Air Stripping:	Not applicable
Oil/Water separation:	Not applicable
Bioremediation:	Yes
Carbon adsorbers:	Yes
Filters: Cuno particulate filters:	Yes
Additive (e.g., chelation agent, flocculent):	Yes (Acetic Acid)
Good condition:	Yes
Sampling ports properly marked and functional:	Yes
Sampling/maintenance log displayed and up-to-date:	Yes
Equipment properly identified:	Yes
Quantity of ground water treated annually:	897,000 gallons*
Quantity of surface water treated annually:	Not applicable
Quantity of soil vapor treated annually:	8,406,000 cubic feet*

* Quantities based on 2011 annual totals.

Remarks: Refer to Section 4.3 (System Operations/Operations and Maintenance of the Building 854 OU Five-Year Review for further details about the Building 854 OU ground water extraction and treatment systems operations and maintenance. Photographs of the ground water extraction and treatment systems are included in Attachment B.

2. Electrical Enclosures and Panels (properly rated and functional)

Good condition: Yes

Remarks: The electrical control panel and enclosure are in good condition, properly rated, and functional.

3. Tanks, Vaults, Storage Vessels

Good condition:	Not applicable
Proper secondary containment	Not applicable

4. Discharge Structure and Appurtenances

Good condition:

Yes

Remarks: The effluent from Building 854 ground water extraction and treatment systems is discharged to infiltration trenches or via misting towers. See table below. A photograph of treatment facility effluent misting tower structure is included in Attachment A.

Treatment System	Discharge Method
854-SRC	Misting towers
854-PRX	Infiltration trench
815-DSB	Infiltration trench

5. Treatment Buildings

Not applicable

6. Monitoring Wells

Properly secured/locked:

Yes

Functioning:

Yes

Routinely sampled:

Yes

Good condition:

Yes

All required wells located:

Yes

Needs maintenance:

None

Remarks: The current Building 854 OU wellfield consists of 5 ground water extraction wells, one soil vapor extraction well, and 27 ground water monitor wells. During 2012, ground water monitoring was conducted in accordance with the CMP monitoring requirements with the following exceptions; twelve required analyses were not performed because the wells were dry or there was insufficient water in the wells to collect the samples.

D. Monitoring Data

1. Monitoring Data

Is routinely submitted on time:

Yes

Is of acceptable quality:

Yes

2. Monitoring data suggests:

Ground water plume is effectively contained:	Yes
Contaminant concentrations are declining:	Yes

Remarks: Refer to Section 7.5.2 (Ground Water Remediation Progress) of the Building 854 OU Five-Year Review for further details on the progress of the remedial action at the Building 854 OU.

E. Monitored Natural AttenuationNot applicable

X. OTHER REMEDIES

If there are remedies applied at the site which are not covered above, attach an inspection sheet describing the physical nature and condition of any facility associated with the remedy:

The soil vapor is extracted at Building 854 from one well. The extracted soil vapor is treated using granular activated carbon. The inspection of the soil vapor system is included in the checklist for the ground water extraction and treatment system in Section IX above.

XI. OVERALL OBSERVATIONS

A. Implementation of the Remedy

Begin with a brief statement of what the remedy is to accomplish (i.e., to contain contaminant plume, minimize infiltration and gas emission, etc.). Describe issues and observations relating to whether the remedy is effective and functioning as designed.

The remedy selected for the Building 854 OU is intended to contain contaminant sources, prevent further plume migration, remove contaminant mass from the subsurface, reduce contaminant concentrations in ground water to cleanup standards, and mitigate VOC inhalation risk to onsite workers. Refer to Section 4.1 (Remedy Section) for further details on the remedial action objectives of the Building 854 OU remedy.

The remedy at the Building 854 OU is effective, functioning as designed, and is protective of human health and the environment for the site's industrial land use. Refer to Section 8 (Technical Assessment) and Section 11 (Protectiveness Statement) of the Building 854 OU Five-Year Review for further details regarding the remedy effectiveness, functionality, and protectiveness.

No deficiencies in the remedy for the Building 854 OU were identified during this evaluation. Refer to Section 9 (Deficiencies) and Section 10 (Recommendations and Follow-up Actions) of the Building 854 OU Five-Year Review for further details regarding deficiency conclusions and recommendations for follow-up actions developed as part of the review process.

B. Adequacy of O&M

Describe issues and observations related to the implementation and scope of O&M procedures. In particular, discuss their relationship to the current and long-term protectiveness of the remedy.

There were no issues or observations related to the implementation and scope of operation and maintenance procedures for the Building 854 OU ground water extraction and treatment facilities.

C. Early Indicators of Potential Remedy Problems

Describe issues and observations such as unexpected changes in the cost or scope of O&M or a high frequency of unscheduled repairs, that suggest that the protectiveness of the remedy may be compromised in the future.

There were no issues or observations that suggest that the protectiveness of the remedy at the Building 854 OU may be compromised in the future. DOE's long-term plans include periodic assessments and upgrades to the Building 854 OU ground water extraction and treatment systems to ensure the effectiveness and protectiveness of the remedy.

D. Opportunities for Optimization

Describe possible opportunities for optimization in monitoring tasks or the operation of the remedy.

Refer to Section 9 (Recommendations and Follow-up Actions) in the Building 854 OU Five-Year Review for further details on DOE recommendations for remedy optimization.

Attachment B

Building 854 Operable Unit Five-Year Review Inspection Checklist

**Ground water and soil vapor extraction and treatment system
photographs**



The Building 854-Source ground water extraction and treatment system (GWTS) began operation in December 1999 removing volatile organic compounds (VOCs) and perchlorate from ground water. Ground water extraction was expanded in September 2006 from one well, W-854-02, extracting at a flow rate of approximately 1 gallons per minute (gpm), to include wells W-854-18A, W-854-17, and W-854-2218 currently extracting at an approximate combined flow rate of 1.7 gpm. The GWTS configuration includes a particulate filtration system, two ion-exchange resin columns connected in series for perchlorate removal, and three aqueous-phase granular activated carbon (GAC) units connected in series for VOC removal. Nitrate-bearing treated effluent is then discharged via a misting tower onto the landscape for uptake and utilization of the nitrate by indigenous grasses (next picture).



Building 854-Source ground water extraction and treatment system misting towers.



The Building 854-Source soil vapor extraction and treatment system (SVTS) began operation in November 2005. Soil vapor is currently extracted from well W-854-1834 at an approximate flow rate of 45 to 50 standard cubic feet per minute (scfm). This system consists of vapor-phase GAC to remove VOCs from extracted soil vapor. Treated vapors are discharged to the atmosphere under a permit issued by the San Joaquin Valley Air Pollution Control District.



The Building 854-Proximal GWTS began operation in November 2000 removing VOCs, nitrate, and perchlorate from ground water. Ground water is currently extracted at an approximate flow rate of 1.5 gpm from well W-854-03, located southeast of the Building 854 complex. The GWTS configuration includes two ion-exchange resin columns connected in series for perchlorate removal, three aqueous-phase GAC units connected in series for VOC removal, and an aboveground containerized wetland biotreatment for nitrate removal prior to being discharged into an infiltration trench. In 2007, the treatment system was modified to replace the solar power with site power to increase the volume of extracted ground water by operating the GWTS 24-hours a day.



The Building 854-Distal GWTS is solar-powered and began operation in July 2006 removing VOCs and perchlorate from ground water. Ground water is extracted from well W-854-2139. The current operational flow rate averaged over time is approximately 700 to 800 gallons per month. The GWTS configuration includes two ion-exchange resin columns connected in series for perchlorate treatment followed by three aqueous-phase GAC units connected in series for VOC removal prior to discharge to an infiltration trench.



**LAWRENCE LIVERMORE
NATIONAL LABORATORY**

Lawrence Livermore National Security, LLC • Livermore, California • 94551